CONNECTICUT RIVER

NEW HAMPSHIRE, VERMONT,
CONNECTICUT AND MASSACHUSETTS

REVIEW OF REPORTS ON FLOOD CONTROL

REPORT

UNITED STATES ENGINEER OFFICE
PROVIDENCE, RHODE ISLAND
FEBRUARY 28, 1940

REVIEW OF REPORTS ON SURVEYS OF THE CONNECTICUT RIVER AND TRIBUTARIES FOR FLOOD CONTROL

R E P O R T

UNITED STATES ENGINEER OFFICE

PROVIDENCE, RHODE ISLAND

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WAR DEPARTMENT
UNITED STATES ENGINEER OFFICE
PROVIDENCE, RHODE ISLAND

February 28, 1940

Subject: Review of reports on surveys for flood control on the Connecticut River and tributaries.

To: The Chief of Engineers, U. S. Army, Washington, D. C.
(Through the Division Engineer)

SYLLABUS

The District Engineer finds that, in the light of the unprecedented storm and floods of September 1938, there is urgent need for a major revision of the existing flood control project on the Connecticut River and tributaries, in order to insure the stability of present development, the social security of the inhabitants, and the preservation of existing values. The Connecticut River may be visited by floods greatly in excess of those which have occurred or have been previously assumed, and increased protection against such floods is warranted. He recommends the adoption of a revised comprehensive plan for flood control, combined with provisions for conservation storage and future power development, substantially as described herein, consisting of 29 reservoirs located on the major tributaries and main river of the Connecticut River, levees and walls at 7 cities, and channel improvements on 2 tributaries, all at an estimated total cost of approximately $104,388,000, inclusive of previous authorizations. Provision for local cooperation in the case of the local protective works is included. The estimated total cost for special multiple-purpose features is $3,722,000, and the estimated total cost for flood control is $100,666,000. The estimated cost to the United States of the flood control features is $98,454,000.

I. GENERAL

1. AUTHORITY.

a. A review of previous reports on the Connecticut River and tributaries was authorized by a Resolution of the Committee on Flood Control of the House of Representatives, United States, adopted June 16, 1938, as follows:

> "Resolved . . . That the Board of Engineers for Rivers and Harbors . . . be, and is hereby requested to review the report on Connecticut River and tributaries, submitted in House Document No. 455, 75th Congress, 2d Session, and previous reports, in order that a review may be had of House Document 412, 74th Congress, 2d Session, with a view to determining whether any modifications of the existing project are advisable as a result of the 1938 flood, especially on Westfield River and at the towns of West Springfield, Hadley, South Hadley, Hatfield and Agawam."

b. The Flood Control Act approved June 22, 1936 (Public No. 738, Seventy-fourth Congress) states:

> "Sec. 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following-named localities, . . ."

and is amended by Section 5 of the Flood Control Act approved August 28, 1937 (Public No. 406, Seventy-fifth Congress), to read:

> "Sec. 5. That section 6 of the Act . . ., approved June 22, 1936, is hereby amended by adding to the list of localities at which preliminary examinations and surveys are authorized to be made the following names:
> "Connecticut and Chicopee Rivers."

The preliminary report for flood control of the Connecticut and Chicopee Rivers was submitted on February 1, 1938. A survey report was directed by the Chief of Engineers by letter dated March 19, 1938. The Chief of Engineers on October 19, 1938, directed the inclusion of the Ware and Quaboag Rivers, tributaries of the Chicopee River, in this report. On January 25, 1939, the District Engineer requested permission to include this latter report in the report for the entire Connecticut River to be submitted under the authority given in Paragraph 1 a above. This request was approved by the Chief of Engineers on February 21, 1939.

c. Section 6 of the Flood Control Act approved August 11, 1939 (Public No. 396, Seventy-sixth Congress), states:

> "Sec. 6. The Secretary of War is hereby authorized and directed to cause to be performed under the supervision of the Chief of Engineers preliminary examinations and surveys for flood control, including floods aggravated by or due to tidal effect, at the following-named localities, . . .:
>
> Connecticut River in the State of Massachusetts between Hatfield town line above Coolidge Bridge and the Narrows at Mount Tom.
>
> Green River, Massachusetts."

2. SCOPE. - This report is a review of House Document No. 455, Seventy-fifth Congress, second session, and previous reports, for flood control, in the light of additional knowledge and data provided by the great flood of September 1938. It presents the results of the preliminary examination for flood control of the Connecticut River in the State of Massachusetts between Hatfield town line above the Calvin Coolidge Bridge and the Narrows at Mount Tom, and the Green River in Massachusetts. It also presents the results of the preliminary examination and survey for flood control of the Connecticut and Chicopee Rivers. It proposes a revised comprehensive plan of reservoirs for the benefit of the entire basin by providing protection for the tributaries and main river valley. It reviews the present authorized local flood-protection works now under construction at seven localities, investigates the economic practicability of additional protection by levees and channel improvements, and presents the results and conclusions. The benefits to be derived from additional storage at flood control reservoirs for power development, conservation for power, recreation, pollution abatement, and wild life have been studied and evaluated, and the results of these studies are stated. Summaries of data on hydrology and meteorology, geology, flood losses, power and conservation, and pollution and the conclusions drawn from them are given in the report proper, together with descriptions, estimates, and the economics of the proposed revised comprehensive plan and its elements. Detailed data, descriptions, and estimates are given in the Appendix.

3. PRIOR REPORTS.

a. Preliminary report. - House Document No. 412, Seventy-fourth Congress, second session, made under the provisions of House Document No. 308, Sixty-ninth Congress, first session, dated February 20, 1935, set forth a comprehensive plan for the Connecticut River Basin consisting of 33 reservoirs, with a total effective storage capacity of 931,000 acre-feet, estimated at that time to cost $41,082,000. All but one of these reservoirs were located in either Vermont or New Hampshire. The reservoirs as a system were set up in a manner that would give a maximum benefit to power and yet allow them to function primarily for the purpose of flood protection. The net storage that would normally be available for flood control during the flood season was 444,000 acre-feet. Ten reservoirs were selected as an initial plan and recommended for construction as a timely measure toward flood control. The gross capacity of these 10 reservoirs was set at 352,500 acre-feet, of which 84,200 acre-feet would be for flood control only. The total cost of the 10 reservoirs was then estimated at $13,373,000.

b. East Hartford.

(1) A report of the flood situation at East Hartford, Connecticut, was submitted by the District Engineer, April 30, 1934, in compliance with instructions of April 10, 1934, from the Chief of Engineers, United States Army. This report was prepared from a study of the flood data and information available at the time. Two general plans of protection designated as Plan A and Plan B were presented. Plan A consisted of a ring dike which inclosed the entire built-up area on the low plain, leaving the swale adjacent to the high ground open for flood flow. Plan B consisted of a U-shaped dike which also inclosed the low developed area and extended across the swale to the high ground east of the meadows, excluding the residential and industrial area on the bluff north of the

New York, New Haven and Hartford Railroad. The estimated costs of Plan A and Plan B with dikes built to an elevation of approximately 33 feet, mean sea level, and with the necessary drainage and pumping facilities, were $602,000 and $658,000, respectively. The information set forth in the report of April 30, 1934, was the basis for Section 1 of the River and Harbor Act approved August 30, 1935, Public No. 409, Seventy-fourth Congress, which authorized:

> "The construction of dikes, drainage gates, suitable pumping plants, and other facilities for controlling floods on the Connecticut River at East Hartford, Connecticut, pursuant to a special survey made by the District Engineer at Providence, Rhode Island, supplementing the survey in House Document Number 308, Sixty-ninth Congress, First Session, and in conformity with either Plan "A" or Plan "B" designated in the report of said supplemental survey: selection of the plan to be executed shall be made by the Secretary of War with the approval of the Town of East Hartford: Provided, that the cost of such work shall not exceed $658,000. Provided further, that the prosecution of this project shall be subject to approval by the Board of Engineers for Rivers and Harbors."

(2) A public hearing was held at East Hartford, January 10, 1936, to secure additional data as to the extent of flood losses, and the views and desires of local interests to supplement the April 30, 1934, report. From information obtained at the public hearing, the report of May 29, 1936, entitled "Preliminary Report, Flood Control at East Hartford, Connecticut," was submitted recommending that a survey be made and that a proposed alternate plan for a dike location north of the New York, New Haven and Hartford Railroad be investigated.

(3) Pursuant to the authorization of survey, a report was submitted by the District Engineer on January 15, 1937, entitled "Report on Flood Control of the Connecticut River at East Hartford, Connecticut." It was recommended therein that the existing project for dikes and other flood control works at East Hartford, Connecticut, be modified to provide for the construction of a project similar to Plan B as designated in the River and Harbor Act approved August 30, 1935, but protecting

to a higher stage, at an estimated construction cost of $845,200 and an estimated cost for rights-of-way, drainage, and pumping facilities of $435,800.

(4) The report on survey and comprehensive plan for flood control in the Connecticut River Valley, dated March 20, 1937, and published as House Document No. 455, Seventy-fifth Congress, second session, recommends works at East Hartford that are substantially the same as those recommended in the report of January 15, 1937, but with an increase in height of 2 feet for earth dikes, at an estimated cost of construction, including pumping plants, of $1,163,000 and an estimated cost of lands, damages, and intercepting sewers and drainage works of $226,000. House Document No. 455 is covered more fully in Paragraph 3 d.

(5) A report of Reexamination of the Connecticut River at East Hartford, Connecticut, was submitted October 21, 1938, and published as Senate Document No. 32, Seventy-sixth Congress, first session. It recommends extension of the existing project to protect the area of East Hartford lying north of the New Haven Railroad, to include Greene Terrace, at an estimated increase in cost to the United States of $249,000, and an estimated increase in cost to be borne by local interests of $9,000.

c. Miscellaneous reports. - Four reports, duly authorized and submitted to higher authority, were returned to the District Engineer for inclusion in the report on survey and comprehensive plan for flood control in the Connecticut River Valley, in accordance with the recommendation of the Board of Engineers for Rivers and Harbors contained in a letter to the Chief of Engineers dated November 26, 1936, which reads:

> "The Board . . . recommends that all authorized outstanding preliminary examinations and surveys on flood control for the Connecticut Basin with the exception of the special report on flood protection at East Hartford, be made the subject of a single comprehensive report for the entire basin, and that the subject matter of the reports on channel improvements below Hartford and Springfield be covered in that report."

The four reports so integrated with the comprehensive report described in Paragraph d below are:

(1) Report on preliminary examination of the Connecticut River, with a view to the control of its floods and prevention of erosion of its banks in the State of Massachusetts, dated January 31, 1935.

(2) Preliminary report with respect to flood control within the Connecticut River Basin, Connecticut, Massachusetts, New Hampshire, and Vermont, dated May 30, 1936.

(3) Supplementary report in connection with proposed channel improvements below Hartford, Connecticut, to the Document 308 Report for the Connecticut River Basin, dated September 25, 1936.

(4) Supplementary report in connection with proposed channel improvement below Springfield, Massachusetts, to the Document 308 Report for the Connecticut River Basin, dated October 1, 1936.

d. House Document No. 455, Seventy-fifth Congress, second session, contains the report on survey and comprehensive plan for flood control in the Connecticut River Valley dated March 20, 1937. This report presents the results of the preliminary examination and survey for flood control of the Connecticut River and its tributaries. It is also a review of House Document No. 412, Seventy-fourth Congress, second session, for flood control, in the light of additional knowledge and data provided by the great flood of March 1936. It proposes a comprehensive plan for flood control consisting of 20 reservoirs, with 10 alternate reservoirs, and dikes at seven cities, at an estimated total cost of $47,000,000. Thirteen of these reservoir sites are located in Vermont, three in New Hampshire, and four in Massachusetts. The reservoirs would provide a flood control capacity of 644,500 acre-feet estimated to cost $34,835,000. The proposed dikes would be located at the cities of Hartford and East

Hartford, Connecticut, and Springfield, West Springfield, Chicopee, Holyoke, and Northampton, Massachusetts, and their estimated total cost is $12,165,000. This estimated total cost was increased to $12,780,000 by the Board of Engineers for Rivers and Harbors to provide for an additional two feet of freeboard. The proposal of the dike at East Hartford was later modified as outlined in Paragraph 3 b (5). The comprehensive plan described in this report was deferred upon recommendation of the Chief of Engineers, and the existing project for the Connecticut River is the initial plan contained in House Document No. 412.

e. Connecticut and Chicopee Rivers.- A preliminary examination report for flood control of the Connecticut and Chicopee Rivers was submitted on February 1, 1938. It recommends a survey report, which is incorporated with this report under authority as outlined in Paragraph 1 b.

f. Navigation reports. - Various navigation reports have been submitted from time to time covering the Connecticut River both above and below Hartford. The latest report for the Connecticut River below Hartford, dated February 24, 1939, and printed as House Document No. 368, Seventy-sixth Congress, first session, recommends no changes in the existing project for improvement of the Connecticut River below Hartford except for provisions for an anchorage at North Cove in the town of Saybrook. This report gives data on prior navigation reports below Hartford. The latest report for the Connecticut River above Hartford, dated May 2, 1938, and printed as House Document No. 165, Seventy-sixth Congress, first session, recommends a modification of the existing project to provide for the construction of a lock, dam, and power plant at Enfield Rapids and for the alteration of bridges by local interests, with 20-foot overhead clearance at a river stage of 16 feet on the Hartford gage. This report gives data on prior navigation reports above Hartford.

4. REPORTS OF OTHER AGENCIES. - Various Federal, state, and local agencies have prepared reports which include physical and flood data on the Connecticut River and its tributaries. A partial list of these containing useful basic data are:

U. S. Geological Survey Water Supply Papers.

Report of the Commission on Waterways and Public Lands on the Water Resources of the Commonwealth of Massachusetts, printed in March 1918 as Massachusetts State Senate Document No. 289.

High Water Data, Flood of March 1936 in Massachusetts, prepared by the Massachusetts Geodetic Survey.

High Water Data, Floods of March 1936 and September 1938 in Massachusetts, prepared by the Massachusetts Geodetic Survey.

Drainage Basin Studies of the Massachusetts State Planning Boards.

Report of Investigation of September 1938 Flood, prepared by a group of consulting engineers for the Department of Public Works of Massachusetts.

The Connecticut River Valley Flood of September 1938 in Connecticut, a bulletin of the Connecticut Ground Water Survey, which was a W.P.A. Project under the sponsorship and direction of the Connecticut State Water Commission.

Several reports on pollution in the Connecticut River and its tributaries have been published and are listed in Section 3 of the Appendix.

5. EXISTING PROJECTS.

a. Dikes at East Hartford, Connecticut. - The River and Harbor Act approved August 30, 1935, Public No. 409, Seventy-fourth Congress, provides that:

"The Secretary of War is authorized and directed to proceed with the construction of dikes, drainage gates, suitable pumping plants, and other facilities for controlling floods on the Connecticut River at East Hartford, Connecticut, pursuant to a special survey made by the District Engineer at Providence, Rhode Island, supplementing the survey in House Document Number 308, Sixty-ninth Congress, first session, and in conformity with either plan A or plan B designated in the report of said supplemental survey; selection of the plan to be executed shall be made by the Secretary of War with the approval of the town of East Hartford: Provided, That the cost of such work shall not exceed $658,000: Provided further, That the prosecution of this project shall be subject to approval by the Board of Engineers for Rivers and Harbors."

This project was subsequently superseded, as noted in Paragraph 5 c.

b. Reservoir system in the Connecticut Valley. - Section 5 of the Flood Control Act approved June 22, 1936, Public No. 738, Seventy-fourth Congress, states:

> "Sec. 5. That pursuant to the policy outlined in sections 1 and 3, the following works of improvement, for the benefit of navigation and the control of destructive flood waters and other purposes, are hereby adopted and authorized to be prosecuted, in order of their emergency as may be designated by the President, under direction of the Secretary of War and supervision of the Chief of Engineers in accordance with the plans in the respective reports and records hereinafter designated: Provided, That penstocks or other similar facilities, adapted to possible future use in the development of adequate electric power may be installed in any dam herein authorized when approved by the Secretary of War upon the recommendation of the Chief of Engineers."
>
> * * * * * * *
>
> "Reservoir system for the control of floods in the Connecticut River valley: Construction of ten reservoirs in Vermont and New Hampshire on tributaries of the Connecticut River; plans in House Document Numbered 412, Seventy-fourth Congress, second session, as the same may be revised upon further investigation of the 1936 flood; estimated construction cost, $10,028,900; estimated cost of lands and damages, $3,344,100."

The wording of this act did not provide for construction of reservoirs in Massachusetts, and it was amended by an Act approved May 25, 1937 (Public No. 111, Seventy-fifth Congress), which states:

> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Act entitled "An Act authorizing the construction of certain public works on rivers and harbors for flood control, and for other purposes", approved June 22, 1936, is hereby amended by changing the paragraph under the heading "Connecticut River Basin," to read as follows:
>
> "Reservoir system for the control of floods in the Connecticut River Valley: Construction of ten reservoirs on the Connecticut River; plans in House Document Numbered 412, Seventy-fourth Congress, second session, as the same may be revised upon further investigation of the 1936 flood; estimated construction cost $10,028,000; estimated cost of lands and damages $3,344,100."

c. Comprehensive Plan for Flood Control in the Connecticut Valley, including levees. - The Flood Control Act approved June 28, 1938, Public No. 761, Seventy-fifth Congress, third session, states:

"The general comprehensive plan for flood control and other purposes as set forth in House Document Numbered 455, Seventy-fifth Congress, second session, is approved, and there is hereby authorized $11,524,000 for the construction of local flood-protection works in said plan: Provided, That the flood-protection project for East Hartford, Connecticut, authorized by the River and Harbor Act of August 30, 1935, is hereby abandoned; all as set forth in House Document Numbered 455, Seventy-fifth Congress, second session."

This Act approves the Comprehensive Plan, and yet authorizes construction of only the local flood-protection works. The only authority for reservoir construction is that contained in the Flood Control Act of 1936, described under Paragraph 5 b, which limits construction to ten reservoirs at an estimated expenditure of $13,373,000. This constitutes the existing project for reservoirs.

d. Navigation.

(1) Above Hartford. - The River and Harbor Act approved July 3, 1930, Public No. 520, Seventy-first Congress, states:

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following works of improvement are hereby adopted and authorized, to be prosecuted under the direction of the Secretary of War and supervision of the Chief of Engineers, in accordance with the plans recommended in the reports hereinafter designated . . .

"Connecticut River, above Hartford, Connecticut: There is authorized to be expended upon the project reported by the Chief of Engineers under date of April 24, 1930, and printed in Rivers and Harbors Committee Document Numbered 36, Seventy-first Congress, second session, subject to the conditions set forth in said report, the sum of $1,000,000, and subject to the further conditions that the Bulkley, or Memorial, Bridge across the Connecticut River at Hartford shall not be disturbed, and that the lock and dam described in the report as to be built near the city of Hartford shall not be constructed so near said city as to in any way disturb city improvements or otherwise interfere with said city."

The project reported in said Document No. 36, which formed the basis of the above authorization, provided for a channel from Hartford to Holyoke, about 32.5 miles, 12 feet deep at mean low water summer stage (with an increase in depth of 1.4 feet through Enfield pool) and generally 100 feet wide, to be secured by the construction of a lock and dam near

Hartford, the construction of a lock and dam by private interests at Enfield Rapids, the lengthening of this lock by the United States, and by dredging and suitable regulating works at a total estimated cost to the United States of $3,384,000 with $85,000 annually for maintenance and operation, all as recommended by the District Engineer in his report printed in Rivers and Harbors Committee Document No. 35 (Seventy-first Congress, second session), subject to the following conditions:

> "(a) That construction shall not begin until the Secretary of War shall be satisfied: (1) That the work at Enfield Rapids under license issued by the Federal Power Commission will be completed; (2) that the bridges will be modified to provide free, easy, and unobstructed navigation as required under existing law, and that such modification will be completed substantially at the same time as the work on the improvement; (b) that the cities of Springfield, Holyoke, and Chicopee shall make suitable provision for terminal facilities satisfactory to the Secretary of War."

The River and Harbor Act approved August 30, 1935, Public No. 409, Seventy-fourth Congress, states:

> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following works of improvement of rivers, harbors, and other waterways are hereby adopted and authorized, to be prosecuted under the direction of the Secretary of War and supervision of the Chief of Engineers, in accordance with the plans recommended in the respective reports hereinafter designated and subject to the conditions set forth in such documents; and that hereafter Federal investigations and improvements of rivers, harbors, and other waterways shall be under the jurisdiction of and shall be prosecuted by the War Department under the direction of the Secretary of War and the supervision of the Chief of Engineers, except as otherwise specifically provided by Act of Congress: . . .
>
> "Connecticut River, above Hartford, Connecticut; House Document Numbered 27, Seventy-third Congress;"

The project reported in said Document No. 27 is as follows:

> "No change is advisable in the project . . . as authorized by the River and Harbor Act of July 3, 1930, in accordance with the report published in House Committee Document No. 36 (71st Cong., 2d sess.), subject to the conditions set forth in the report and in the act of authorization except that the condition with respect to the construction of the lock and dam at Enfield Rapids be broadened to provide for such construction by State, municipal, or private interest under license issued by the Federal Power Commission."

Since the condition with respect to construction of the lock and dam at Enfield Rapids has not been met, no initial work toward execution of the project has been undertaken by the United States, and no appropriation has been made.

(2) Below Hartford. - River and Harbor Acts from time to time established a project in the Connecticut River below Hartford, Connecticut, having a channel generally 100 feet wide and 12 feet deep. The River and Harbor Act approved August 30, 1935, Public No. 409, Seventy-fourth Congress, reads:

> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following works of improvement of rivers, harbors, and other waterways are hereby adopted and authorized, to be prosecuted under the direction of the Secretary of War and supervision of the Chief of Engineers, in accordance with the plans recommended in the respective reports hereinafter designated and subject to the conditions set forth in such documents; and that hereafter Federal investigations and improvements of rivers, harbors, and other waterways shall be under the jurisdiction of and shall be prosecuted by the War Department under the direction of the Secretary of War and the supervision of the Chief of Engineers, except as otherwise specifically provided by Act of Congress: . . .
>
> "Connecticut River below Hartford, Connecticut; House Document Numbered 49, Seventy-third Congress;"

The project reported in said Document No. 49 provides for a channel 15 feet deep at mean low water and 300 feet wide from the mouth to the Lyme railroad bridge, thence 150 feet wide to Hartford.

e. Miscellaneous projects. - There has been some miscellaneous levee work done by local interests and by Work Relief projects. Where pertinent, the extension of these projects has been considered a part of the comprehensive plan (see Paragraph 5 c above).

II. DESCRIPTION OF WATERSHED

6. A complete description of the watershed was given in House Document No. 455, Seventy-fifth Congress, second session. No changes in the watershed have occurred to warrant further description at this time.

III. HYDROLOGY AND METEOROLOGY

7. GENERAL. - A detailed discussion of the hydrology and meteorology of the Connecticut River Basin was given in House Document No. 455, Seventy-fifth Congress, second session. The information presented there is subject to some revision as a result of the great storm and flood of September 1938, which occurred subsequent to the submission of that report.

8. THE STORM OF SEPTEMBER 1938. - Heavy rainfall occurred over the New England region on September 12 and 13, 1938. The rainfall accompanied a low-pressure area which moved from the Hudson Bay region on the 12th and centered over northern New England on the 13th. Meanwhile a low-pressure area developed over the Central States. On the 14th the New England low moved northeast to the Maritime Provinces, and the Central States low moved eastward over the southern Lake region, causing moderate precipitation. By the 15th the latter low-pressure disturbance had moved over the St. Lawrence Valley. Heavy rains occurred over New England on the 14th and 15th. On the 16th the low area had moved northeast, and a well developed trough of low pressure appeared along the Atlantic Coast as far south as Georgia. The low-pressure area forming the southernmost end of this trough, after remaining stagnant for three days, moved northward and was centered off Delaware on September 20th. Meanwhile another low-pressure area, moving eastward from the Great Lakes area, centered over the St. Lawrence region. Large masses of moisture-laden air passed inland over New England and resulted in rainfall of unprecedented magnitude. The heavy precipitation lasted from the evening of September 18th to the

afternoon of September 21st, exceeding 10 inches in the vicinity of Hartford, Connecticut, and Springfield, Massachusetts, and decreasing to about 4 inches in the northern part of the Connecticut River watershed. On the 20th a tropical hurricane centered east of Florida. It moved northward with unprecedented speed, traversing the elongated low-pressure area and passing up the Connecticut River watershed on the afternoon of the 21st. The passage of the hurricane dissipated the stagnant atmospheric condition and ended the rainfall, with minor exceptions. The total rainfall for the period from September 18th to September 21st reached a maximum of 17 inches at each of two centers, one located in east central Connecticut, and the other in Massachusetts. The average total rainfall over the Connecticut River Basin above Hartford amounted to 7.45 inches. The hourly raingraphs for recording rainfall stations in and near the basin are shown on Plates Nos. 2 and 3, Section 1 of the Appendix. The isohyetal map of the total rainfall for the period September 17-21, inclusive, are shown on Plate No. 4, Section 1 of the Appendix.

9. THE FLOOD OF SEPTEMBER 1938. - The storm of September 1938 occurred at a time when conditions were reasonably favorable for a high run-off. Heavy and well-distributed rainfall had occurred during the preceding summer months, resulting in a high degree of ground water saturation. In addition, the storm was preceded by heavy rains on September 12th, by about one inch of rainfall over the entire Connecticut Basin on September 14th and 15th and about one-half inch on September 17th, raising tributaries close to bank-full stages prior to the main storm.

a. Tributaries. - The tributaries in the area of greatest rainfall, which included Connecticut, Massachusetts, and southern Vermont and New Hampshire, exceeded all previous peak discharges of record. Tributary discharges diminished farther to the north. Flood crests on the

principal Vermont tributaries south of the White River exceeded those of March 1936, but were somewhat less than those of November 1927, the greatest flood of record in that area. Above the mouth of the White River, the tributary floods were not particularly severe. Discharge hydrographs for the flood of September 1938 as recorded at U. S. Geological Survey gaging stations on the various tributaries are shown on Plate No. 6, Section 1 of the Appendix. As shown, peak discharges generally occurred on September 21st or early on the 22nd. Table III, Section 1 of the Appendix shows the volumes and peak discharges of the 1927, 1936, and 1938 floods for stations on the tributaries and the main stem.

b. Main stem. - The main stem of the Connecticut River was not in flood above the mouth of the White River. Below the mouth of the White River, the relative magnitude of the flood increased progressively downstream. The Connecticut River crested at Hartford on the afternoon of September 23rd, reaching a peak discharge of 251,000 cubic feet per second. The total run-off volume was 4.39 inches. On the lower main stem, the flood of September 1938 was the second highest of record, being exceeded only by the flood of March 1936. Above Montague City, the floods of November 1927 and March 1936 were greater, and above White River Junction several other floods of record exceeded that of September 1938. Discharge hydrographs for the flood of September 1938 at various points on the main stem are shown on Plate No. 5, Section 1 of the Appendix.

10. DESIGN FLOOD. - A greater flood than any of record on the Connecticut River might result from a great storm under conditions favorable to a high run-off. Such an hypothetical design flood is necessary for use in selecting a comprehensive plan of flood control. To evaluate this design flood, a very large storm was selected which might reasonably be expected to occur, and would produce a flood somewhat more severe than

any of record. This hypothetical storm was selected by orienting the storm of September 1938, as defined by its isohyetals, over the Connecticut Watershed in such a way that the heaviest rainfall occurs over the greatest flood-producing areas. The shifted isohyetals are shown on Plate No. 10, Section 1 of the Appendix. The duration of the storm of September 1938 was generally 96 hours. The duration of the design-flood storm was selected as 72 hours. Values from the maximum 6, 12, and 96-hour isohyetals of the storm of September 1938 determined three area-depth curves. For a drainage area of 10,000 square miles, an intensity-duration curve was determined by plotting a value from each area-depth curve, with the value from the 96-hour area-depth curve being plotted at 72 hours. Unit graphs had previously been determined for selected local areas upstream from the points where design-flood hydrographs were desired. For each of these areas, the total volume of rainfall for the design flood was determined by taking the average depth of the shifted isohyetals over each area. The intensity of rainfall for each area was made proportional to the above intensity-duration relation, with the heaviest rainfall occurring at 36 hours, and with a roughly symmetrical distribution over 72 hours. To compute the design flood at the points desired, the rainfall for each contributing area was applied to the unit graphs with an infiltration rate of .05 inch per hour. The resulting discharge hydrographs were then routed to the points desired. The design flood determined by this method diminishes in severity in the upper portion of the watershed. Consequently, to determine the design flood at points above Montague City, the volume of rainfall was taken from the area-depth relation for the storm of September 1938, with the same duration, intensity-distribution, and infiltration rate as described above. The design flood in this area was computed similarly by the use of unit graphs for local areas, and by routing to the index station. The

discharge hydrographs for the design flood at three points on the Connecticut River are shown on Plate No. 11, Section 1 of the Appendix. The run-off volume of the design flood, at Hartford, is equivalent to a depth of 6.03 inches on the contributing drainage area of 10,643 square miles. The volume of the design flood at six points on the Connecticut River is shown in Table VI, Section 1 of the Appendix. From the foregoing it is seen that the design flood was deduced by rational methods from rainfall assumptions conservatively within the probability of occurrence in the light of records and meteorological studies.

11. DEMONSTRATION FLOOD. - For comparison with the design flood, a demonstration flood resulting from a storm of constant volume over the entire watershed was selected, such that the peak discharge at Hartford would be equal to that of the design flood. The storm has a duration of 72 hours, and a resulting run-off volume of 7.0 inches over the entire watershed. This run-off volume could be realized from a larger volume of rain with variable run-off conditions, or, in winter, from a smaller volume of rain falling on melting snow. The time-intensity distribution assumed for this storm was a constantly increasing rate for the first 36 hours, and a constantly decreasing rate for the last 36 hours. The demonstration flood was built up at the points desired by the use of unit graphs and flood routing, as in the case of the design flood. The resulting discharge hydrographs for the demonstration flood at three points on the Connecticut River are also shown on Plate No. 11, Section 1 of the Appendix.

12. FLOOD FREQUENCIES.

a. Peak discharge. - A revision of the frequency studies made for House Document No. 455, Seventy-fifth Congress, second session, was necessary because of the availability of additional records since the publication of that Document. Peak discharge-frequency relations were plotted using the basic-stage method for each gaging station in the

Connecticut River Watershed having a period of record longer than 12 years. For tributaries they are shown on Plates Nos. 7 and 8, Section 1 of the Appendix, and for the main stem they are shown on Plate No. 9, Section 1 of the Appendix. Values from these curves were plotted versus the drainage area, with frequency as parameters. These empirical relations fell into four geographical groups, three for the tributaries and one for the main stem, as shown on Plate No. 9, Section 1 of the Appendix. The relation for a few tributaries in the extreme northwestern part of the watershed did not agree with those determined for either of the three tributary groups, but investigations showed that the relation for these few tributaries could be determined by multiplying the peak discharge values obtained from the nearest geographical group by a constant. The empirical relations were then used to determine the peak discharge-frequency relation at points other than gaging stations where the relation was desired.

b. Volume. - The same volume-frequency relations of floods derived for House Document No. 455, Seventy-fifth Congress, second session, were used for this report.

IV. FLOOD LOSSES

13. GENERAL. - The Connecticut River Basin suffers frequently and severely from floods. Realization of the extent of the losses has become acute with the occurrence of the great floods of 1927 and 1936, and more recently, the flood of 1938. The total direct losses in the Connecticut Valley in the 13-year period since 1927 have amounted to over $80,000,000. Because the valleys are highly developed, floods have caused loss of life and great damage, and will cause larger losses in the future as a result of the progressive urban and industrial growth of the region. The losses from recent floods, particularly those of 1936 and 1938, have been thoroughly investigated. Classified as direct, indirect, and depreciation losses, they form the basis for the computation of average annual losses and average annual benefits to be derived from flood control measures. These benefits form the principal economic justification for flood protection.

14. FLOOD LOSSES OF RECORD. -

a. Losses prior to 1936. - Only incomplete records are available, except for the outstanding floods of 1927 and 1936 which are described in more detail in the report of the Connecticut River published as House Document No. 455, Seventy-fifth Congress, second session. The flood of November 1927 caused direct losses of $15,526,000, and took 15 lives. The flood was most severe in the upper watershed, where 70 percent of the damage occurred in Vermont, with particularly great losses along the White and Passumpsic Rivers. In many localities, largely because of the high velocities of the steep streams in the upper watershed, there were disastrous washouts of houses, village streets, highways, and railroads. Losses in March 1936 were larger, totaling $34,500,000 direct damage, and five lives, with greatest losses in the important urban and industrial centers of the lower valley where previous flood crests were

exceeded by 6 to 8 feet. Approximately 10,000 homes were flooded in an inundated area of 64,000 acres. As a result, property in portions of the flood plain has become degraded to a lower class of occupancy, and high-grade tobacco land has reverted to lower usage. Direct losses of 1936 and 1927 are summarized in Table I.

(Table I on following page)

TABLE I

DIRECT FLOOD LOSSES - FLOODS OF 1927, 1936, AND 1938

CONNECTICUT RIVER WATERSHED

BY STATES

STATE	FLOOD DAMAGE		
	November 1927	March 1936	September 1938
Vermont	$10,981,000	$1,765,000	$ 3,809,000
New Hampshire	1,767,000	2,342,000	1,125,000
Massachusetts	2,157,000	19,000,000	15,553,000**
Connecticut	621,000	11,393,000	5,109,000**
Total Direct Losses	15,526,000	34,500,000	25,596,000
Loss of Life	15	5	8

BY TRIBUTARIES

RIVER BASIN	STATE	1927	1936	1938
Connecticut	Conn., Vt., N. H., & Mass.	$4,007,000	$27,533,000	$6,396,000**
Israel	N. H.	62,000	24,000	16,000*
Passumpsic	Vt.	2,584,000	72,000	9,000
Stevens	Vt.	23,000	3,000	2,000
Wells	Vt.	636,000	5,000	6,000
Ammonoosuc	N. H.	980,000	135,000	64,000
Waits	Vt.	56,000	4,000	6,000
Ompompanoosuc	Vt.	93,000	1,000	11,000
White	Vt.	4,181,000	42,000	308,000
Mascoma	N. H.	--*	95,000	57,000
Ottauquechee	Vt.	532,000	15,000	280,000
Sugar	N. H.	--*	143,000	40,000
Black	Vt.	716,000	74,000	398,000
Williams	Vt.	63,000	10,000	209,000*
Saxtons	Vt.	59,000	15,000	191,000*
Cold	N. H.	--*	36,000	24,000*
West	Vt.	501,000	139,000	823,000
Ashuelot	N. H.	--*	536,000	613,000
Millers	Mass.	--*	2,597,000	3,728,000
Deerfield	Mass. & Vt.	--*	440,000	4,108,000
Chicopee	Mass.	--*	1,419,000	4,781,000
Westfield	Mass.	992,000	384,000	1,341,000
Farmington	Mass. & Conn.	41,000	355,000	1,254,000
Misc. other streams	(Various)	--*	443,000	928,000 *
Total Direct Losses		15,526,000	34,500,000	25,596,000

*No detailed investigation.
**Incomplete investigation on Connecticut River in states of Massachusetts and Connecticut.

b. Losses of September 1938. - The great flood of September 1938 was accompanied by disastrous hurricane winds. The flood losses, exclusive of wind damage, reached a total of $25,596,000 of direct loss; in addition 8 lives were lost. Tributary streams below White River Junction, Vermont, caused excessive damage. The Ottauquechee and Black Rivers in Vermont, and the Mascoma and Sugar Rivers in New Hampshire crested at stages about equal to the flood of 1927, although damage was somewhat less. Record stages and damage occurred on the streams in lower Vermont and New Hampshire, and in Massachusetts and Connecticut. Tributary streams forced over 7,000 families out of their homes, damaged about 1,250 industrial and commercial establishments, flooded nearly 16,000 acres of farm lands, and wrecked approximately 530 highway and railroad bridges. Failures or washouts at 30 important dams increased damage by adding to flood heights. Damage on tributary streams totaled $19,200,000, compared with approximately $7,000,000 in the flood of 1936. The Connecticut River main stem did not cause so much damage as in 1936, though over 4,700 families evacuated their homes and 6,200 acres of crop lands were flooded. Two hundred industrial and commercial establishments were flooded. Normal activities were halted by closing of the bridges across the Connecticut River and failure of power supply as a result of flood and wind damage. The Connecticut River caused only moderate damage in Vermont and New Hampshire for the crest ranged from about 12 feet below the 1936 peak in the upper valley to about 5 feet below in the lower reaches. The flood increased as it progressed downstream towards the main damage centers of Springfield, Massachusetts, and Hartford, Connecticut, where it crested only two to three feet below the 1936 peak. Damage in the seven major damage centers on the lower Connecticut River totaled approximately $4,000,000 in 1938 compared with $19,000,000 in 1936. The lesser damage in 1938 is partly due to the difference in flood stage of

two to three feet, but principally due to (1) savings of approximately $6,000,000 by levees partly completed by the U. S. Engineer Department, (2) improved flood warnings and emergency protective measures, and (3) absence of ice. The direct flood losses of 1938 on the Connecticut River and tributary streams are described in further detail in Section 2 of the Appendix. They are summarized in Table I.

15. AVERAGE ANNUAL FLOOD LOSSES.

a. Annual direct losses were determined from flood losses of record allocated to "damage zones" or reaches below proposed reservoirs, and reduced for nonrecurring losses. Recurring losses are summarized in Table II for the flood of record in each zone. The relation between damage and flood stage or discharge was determined from detailed field investigation and combined with the discharge-frequency relation, from stream flow records, to determine the damage-frequency relationship and average annual damage. The natural direct loss-frequency relation was plotted between 100 and 1.0 percent chance of occurrence. Between 1.0 percent and 0 percent chance the curve was distorted to the value of the direct loss from a flood having a 0.1 percent chance of occurrence. In effect, this includes the losses from one flood, having a 0.1 percent chance of occurrence, during the assumed economic life of the improvement. The average annual direct loss was then taken as the mean ordinate of the entire 100 percent chance period. The average annual losses would have been much greater if the curve between 1.0 percent and 0 percent chance had been distorted to the value of the direct loss from the design flood described in Paragraph 10 of this report. This would have included the losses from one design flood occurring during the assumed economic life of the improvement, thereby placing more weight on this flood which was computed by rational methods, and less weight on the discharge-frequency relationships derived from relatively short-time records. However, the method giving the most conservative average annual losses was used. Section 2 of the Appendix describes the method in further detail.

(Table II on pages 25 and 26)

TABLE II

DIRECT FLOOD LOSSES--CONNECTICUT RIVER WATERSHED
SUMMARY OF RECURRING LOSSES BELOW RESERVOIR SITES CONSIDERED
BASED UPON 1927, 1936, & 1938 FLOODS.

DIRECT RECURRING FLOOD LOSS

RIVER	ZONE	YEAR OF MAX. FLOOD	URBAN*	RURAL	INDUSTRIAL**	HIGHWAY	RAILROAD	TOTAL
CONNECTICUT	VT., N.H. 1	'36	$31,700	$23,400	$14,200	$6,700	$26,600	$102,600
"	VT., N.H. 2	"	18,700	27,600	6,100	146,400	38,000	236,800
"	VT., N.H. 3	"	37,500	21,100	158,700	11,500	34,400	263,200
"	VT., N.H. 4	"	5,300	24,100	12,000	282,300	48,600	372,300
"	VT., N.H. 5	"	17,200	79,900	179,500	212,800	296,700	786,100
"	MASS.,VT., N.H. 6	"	2,200	214,600	4,900	140,100	191,400	553,200
"	MASS. 7	"	1,097,300	484,900	1,652,500	623,600	117,300	3,976,100
"	MASS. 8	"	3,527,200	61,700	3,545,500	538,600	171,000	7,344,100
"	CONN. 9	"	47,500	36,200	199,500	38,300	7,900	329,400
"	CONN. 10	"	3,372,400	313,800	5,854,300	770,500	108,800	10,419,800
TOTAL FOR CONN. RIVER			8,157,000	1,287,300	11,627,200	2,770,800	1,041,300	24,983,600
TRIBUTARY STREAMS								
PASSUMPSIC	VT. 1A	'27	8,400	18,000	25,000	57,000	60,000	168,400
"	VT. 1B	"	110,800	19,000	24,500	145,000	80,000	379,300
"	VT. 1C	"	51,300	5,100	85,700	123,000	90,000	355,100
" (MOOSE)	VT. 1D	"	3,100	2,500	5,000	12,000	16,000	38,600
STEVENS	VT. 2A	"	1,500	-	700	15,000	-	17,200
WELLS	VT. 3A	"	66,300	4,200	30,000	45,300	87,300	233,100
AMMONOOSUC	N.H. 4A	"	3,400	9,000	30,600	22,000	3,000	68,000
"	N.H. 4B	"	18,000	25,400	20,000	31,100	14,900	109,400
"	N.H. 4X	"	30,800	-	-	15,000	6,100	51,800
"	N.H. 4Y	"	1,400	1,400	2,800	3,500	-	14,100
WAITS	VT. 5A	"	-	800	1,000	2,000	-	3,800
WHITE	VT. 7A	"	5,100	21,800	-	55,200	1,000	83,100
"	VT. 7B	"	2,700	-	-	5,000	7,000	14,700
"	VT. 7C	"	4,000	-	-	30,000	-	34,000
"	VT. 7D	"	25,700	20,500	-	33,000	-	79,200
"	VT. 7E	"	10,000	-	137,600	-	-	147,600
"	VT. 7V	"	-	700	3,000	-	1,700	5,400
"	VT. 7W	"	-	-	-	-	-	-
"	VT. 7X	"	2,200	-	-	7,200	-	9,400
"	VT. 7Y	"	8,200	18,800	-	33,000	-	60,000
MASCOMA	N.H. 8A	'36	300	-	200	400	1,300	2,200
"	N.H. 8B	"	36,400	1,100	2,100	100	500	40,200
OTTAUQUECHEE	VT. 9W	'38	1,500	1,700	83,000	2,000	-	88,200
SUGAR	N.H.10A	'36	-	300	2,300	200	100	2,900
"	N.H.10B	"	4,600	500	3,300	100	-	8,500
"	N.H.10C	"	100	-	-	1,100	-	1,200
"	N.H.10W	"	700	1,700	500	1,400	1,400	5,700
BLACK	VT. 11A	'38	86,900	5,500	14,200	10,000	-	116,600
"	VT. 11B	"	-	4,200	-	-	-	4,200
"	VT. 11C	"	16,100	2,600	18,300	-	-	37,000
SAXTONS	VT. 12A	'27	-	-	-	8,300	-	8,300
WEST	VT. 13A	'38	300	2,900	1,200	15,000	-	19,400
"	VT. 13Y	"	37,500	-	-	45,000	-	82,500
"	VT. 13Z	"	800	15,500	1,000	15,000	-	32,300
ASHUELOT	N.H. 14A	"	2,400	100	-	3,300	-	5,800
"	N.H. 14B	"	98,400	13,000	97,000	3,700	21,000	233,100
"	N.H. 14C	"	54,800	31,900	64,400	3,500	6,500	161,100
"	N.H. 14F	"	700	-	18,700	9,500	1,200	30,100
"	N.H. 14M	"	500	1,100	500	700	-	2,800
"	N.H. 14X	"	6,000	1,700	11,900	14,500	-	34,100
MILLERS	MASS. 15C	"	18,600	9,000	59,000	36,300	12,600	135,500
"	MASS. 15E	"	2,100	-	67,300	11,000	24,600	105,000
"	MASS. 15G'	"	467,300	24,700	442,700	41,800	70,100	1,046,600
"	MASS. 15H'	"	1,500	800	113,100	41,600	527,400	684,400
"	MASS. 15D	"	100	600	-	3,900	-	4,600
"	MASS. 15F	"	-	-	-	3,000	-	3,000
"	MASS. 15X	"	36,000	4,500	201,700	24,500	165,200	431,900

TABLE II (CONTINUED)

RIVER	ZONE	YEAR OF MAX. FLOOD	URBAN*	RURAL	INDUSTRIAL**	HIGHWAY	RAILROAD	TOTAL
DEERFIELD	MASS. 16U	'38	21,300	14,400	130,200	23,100	88,500	280,500
"	MASS. 16V	"	52,800	53,400	50,100	7,400	19,600	183,300
"	MASS.,VT. 16W	"	2,700	100	2,700	20,000	-	25,500
"	MASS.,VT. 16X	"	54,100	70,900	31,800	70,900	-	227,700
"	VT. 16Y	"	-	-	7,300	3,600	-	10,900
"	VT. 16Z	"	66,000	-	-	60,500	-	126,500
CHICOPEE	MASS. 22A	"	-	-	1,300	-	1,000	2,300
"	MASS. 22B	"	341,300	69,900	785,200	59,000	38,500	1,293,900
"	MASS. 17A	"	-	3,000	16,800	-	-	19,800
"	MASS. 21A	"	19,900	14,300	4,100	7,000	15,500	60,800
"	MASS. 21B	"	38,400	11,400	101,200	31,100	15,200	197,300
"	MASS. 17B	"	179,100	13,800	342,200	95,400	3,000	643,500
WESTFIELD	MASS. 18A	"	1,700	400	1,600	1,800	500	6,000
"	MASS. 18B	"	117,300	8,700	225,600	33,100	12,000	396,700
"	MASS. 18C	"	10,600	10,800	1,200	21,500	1,100	45,200
"	MASS. 18V	"	6,100	1,700	3,000	71,000	-	81,800
"	MASS. 18W	"	26,600	1,600	35,100	9,800	9,500	82,600
"	MASS. 18X	"	600	400	-	18,400	-	19,400
FARMINGTON	MASS. 19U	"	10,000	-	700	20,400	-	31,100
"	CONN. 19V	"	50,600	14,000	107,200	53,300	200	225,300
"	CONN. 19W	"	70,000	17,600	83,600	98,500	23,000	297,700
"	CONN. 19X	"	31,900	323,200	13,800	600	7,900	377,400
"	CONN. 19Y	"	63,400	1,400	6,400	25,500	3,000	104,700
TOTAL FOR TRIBUTARY STREAMS			2,395,900	906,600	3,527,400	1,667,100	1,442,400	9,939,400
GRAND TOTAL			10,552,900	2,193,900	15,154,600	4,437,900	2,483,700	34,823,000

* INCLUDES RESIDENTIAL, COMMERCIAL, AND PUBLIC.
** INCLUDES UTILITY.

b. Annual indirect losses were computed as a percentage of the direct losses, as determined from detailed studies in typical areas by methods of sampling and rational analysis. The percentages for the individual reaches varied from 115 for industrial areas to 20 for rural areas. Indirect losses, which include losses of business and wages, costs of relief, and similar losses both within and without the flood area, are more thoroughly covered in Section 2 of the Appendix.

c. Depreciation losses, which result from decreases in the value and utility of property, caused by recent floods, were based upon comparison of true sales, reductions in assessments, and opinions of bankers, real estate operators, owners, tenants, and other qualified individuals. Real estate affected by these floods had a value of approximately $393,498,000 before 1936, when only normal floods had been experienced throughout much of the area. As a result of the 1936 and 1938 floods, real estate values, which reflect property utilization and desirability, have been depressed approximately $83,739,000 excluding the capitalized value of annual direct and indirect losses. Without protective works an average recoverable real estate loss of at least one-half this amount will remain as an annual loss of 5 percent to property owners and 2 percent to communities. The private property subject to a flood having a 0.1 percent chance of occurrence, within the damage zones, represents a total value of approximately $518,150,000, real estate and personal property. There is an additional $77,881,000 of railroad, highway, and public property affected. Valuation of property and other related data are summarized in Table III.

(Table III on pages 28 and 29)

TABLE III

VALUATION DATA
CONNECTICUT RIVER WATERSHED

RIVER	ZONE	STATE	TOTAL POPULATION 1930 CENSUS	PRE-FLOOD VALUATION REAL & PERSONAL PROPERTY: TOTAL ASSESSED	PRE-FLOOD VALUATION REAL & PERSONAL PROPERTY: MAXIMUM FLOOD AREA**	EXISTING DEPRECIATION OF REAL ESTATE FROM FLOODS OF 1936 & 1938*	INCREASE OF LAND VALUE WITH PROTECTION
CONNECTICUT	C-1	VT.-N.H.	7,702	$ 15,711,821	$ 1,364,000	$ 5,700	$ 0
"	C-2	VT.-N.H.	8,728	11,185,628	1,044,000	5,500	0
"	C-3	VT.-N.H.	10,881	10,689,945	4,895,000	127,100	0
"	C-4	VT.-N.H.	6,750	10,662,440	3,418,000	4,500	0
"	C-5	VT.-N.H.	16,780	20,324,815	8,080,000	195,700	0
"	C-6	VT.-N.H. & MASS.	3,505	3,891,885	536,000	4,100	0
"	C-7	MASS.	132,630	191,200,194	66,328,000	6,500,000	828,000
"	C-8	MASS.	216,946	397,231,774	264,007,000	32,857,000	2,754,000
"	C-9	CONN.	30,638	44,648,075	18,140,000	430,000	122,000
"	C-10	CONN.	250,264	484,103,339	267,983,000	38,210,000	8,126,000
TOTAL FOR CONNECTICUT RIVER			684,824	1,189,648,916	636,395,000	78,339,600	11,830,000
PASSUMPSIC	1-A	VT.	800	861,000	331,000	0	0
"	1-B	VT.	6,671	5,850,133	3,548,000	127,500	0
"	1-C	VT.	5,094	4,323,676	1,996,000	68,000	0
"	1-D	VT.	2,234	1,598,673	583,000	0	0
STEVENS	2-A	VT.	260	266,000	154,000	0	0
WELLS	3-A	VT.	1,869	1,459,648	891,000	34,000	0
AMMONOOSUC	4-A	N.H.	5,580	8,702,448	1,718,000	0	0
"	4-B	N.H.	2,274	3,152,412	1,002,000	14,000	42,000
"	4-X	N.H.	14,277	1,499,475	942,000	0	0
"	4-Y	N.H.	664	1,143,916	372,000	0	0
WAITS	5-A	VT.	370	331,000	208,000	3,100	0
WHITE RIVER	7-A	VT.	2,110	1,359,788	216,000	3,400	0
" "	7-B	VT.	1,491	848,231	39,000	0	0
" "	7-C	VT.	910	1,048,281	184,000	2,600	0
" "	7-D	VT.	1,837	1,745,000	570,000	11,900	0
" "	7-E	VT.	1,325	1,620,000	400,000	0	0
" "	7-V	VT.	632	772,640	264,000	4,800	0
" "	7-W	VT.	0	0	0	0	0
" "	7-X	VT.	2,604	1,474,000	435,000	3,100	0
" "	7-Y	VT.	2,048	1,286,600	479,000	0	0
MASCOMA	8-A	N.H.	2,175	1,115,520	586,000	4,400	0
"	8-B	N.H.	8,400	7,716,128	2,784,000	43,000	0
OTTAUQUECHEE	9-W	VT.	8,500	3,489,770	1,889,000	27,800	0
SUGAR	10-A	N.H.	7,836	4,608,470	63,000	0	0
"	10-B	N.H.	9,877	11,193,480	7,174,000	0	39,000
"	10-C	N.H.	906	637,009	45,000	0	0
"	10-W	N.H.	9,531	6,752,050	1,547,000	3,600	0
BLACK	11-A	VT.	-	2,600,210	2,637,000	33,000	-
"	11-B	VT.	0	0	201,000	6,200	0
"	11-C	VT.	4,443	8,494,052	3,733,000	124,000	0
SAXTONS	12-A	VT.	-	10,725,688	575,000	0	0
WEST	13-A	VT.	1,832	1,553,850	185,000	0	0
"	13-Y	VT.	-	833,200	443,000	23,400	0
"	13-Z	VT.	-	1,211,100	374,000	0	0

TABLE III (CONTINUED)

RIVER	ZONE	STATE	TOTAL POPULATION 1930 CENSUS	PRE-FLOOD VALUATION REAL & PERSONAL PROPERTY		EXISTING DEPRECIATION OF REAL ESTATE FROM FLOODS OF 1936 & 1938*	INCREASE OF LAND VALUE WITH PROTECTION
				TOTAL ASSESSED	MAXIMUM FLOOD AREA**		
ASHUELOT	14-A	N.H.	2,147	$ 794,000	$ 525,000	$ 29,900	$ 0
"	14-B	N.H.	11,647	17,066,504	14,186,000	700,000	86,000
"	14-C	N.H.	3,799	4,095,508	1,123,000	0	0
"	14-T	N.H.	1,857	4,866,985	1,532,000	0	0
"	14-M	N.H.	53	122,182	112,000	8,000	0
"	14-X	N.H.	2,020	2,167,308	499,000	25,100	0
MILLERS	15-C	MASS.	6,202	9,141,929	2,126,000	154,300	0
"	15-E	MASS.	6,094	11,279,710	6,543,000	158,500	0
"	15-G	MASS.	10,628	18,877,000	15,289,000	716,000	0
"	15-H	MASS.	630	5,165,840	4,081,000	194,000	0
"	15-D	MASS.	5,904	0	22,000	0	0
"	15-F	MASS.	1,050	0	0	0	0
"	15-X	MASS.	4,019	5,169,520	1,188,000	74,300	0
DEERFIELD	16-U	MASS.	1,704	3,493,716	1,803,000	0	0
"	16-V	MASS.	2,869	6,117,849	2,765,000	0	0
"	16-W	VT.&MASS.	15,792	30,179,339	72,000	0	0
"	16-X	VT.&MASS.	4,107	5,759,348	1,342,000	26,800	0
"	16-Y	VT.	1,100	928,624	135,000	0	0
"	16-Z	VT.	8,800	2,916,494	716,000	12,700	0
CHICOPEE	22-A	MASS.	351	516,300	330,000	0	0
"	22-B	MASS.	16,351	15,562,400	13,698,000	825,000	565,000
"	17-A	MASS.	3,283	4,365,000	915,000	0	0
"	21-A	MASS.	7,025	9,722,000	569,000	9,700	0
"	21-B	MASS.	9,044	20,109,000	2,314,000	0	0
"	17-B	MASS.	29,351	74,625,000	33,594,000	912,000	237,000
WESTFIELD	18-A	MASS.	703	527,170	165,000	0	0
"	18-B	MASS.	1,552	30,338,987	22,795,000	329,000	252,000
"	18-C	MASS.	35,906	20,244,480	525,000	0	0
"	18-V	MASS.	1,055	1,237,938	153,000	700	0
"	18-W	MASS.	3,245	4,408,615	1,308,000	9,800	0
"	18-X	MASS.	-	94,100	16,000	0	0
FARMINGTON	19-U	MASS.	612	402,469	119,000	0	0
"	19-V	CONN.	3,391	5,466,552	2,176,000	0	0
"	19-W	CONN.	8,027	12,270,645	3,040,000	71,000	0
"	19-X	CONN.	19,204	24,755,563	2,919,000	179,000	0
"	19-Y	CONN.	9,371	15,215,587	6,442,000	362,800	0
TRIBUTARY TOTAL			345,443	468,274,158	181,755,000	5,599,4[illegible]	1,221,000
TOTAL REAL & PERSONAL PROPERTY					318,150,[illegible]		
TAX EXEMPT PROPERTY AFFECTED (PUBLIC & HIGHWAY)					57,551,000		
RAILROAD PROPERTY AFFECTED (APPROXIMATE)					20,330,000		
TOTALS			1,030,267	$1,657,924,074	$ 696,[illegible]31,[illegible]	$63,739,[illegible]	$13,051,000

* EXCLUSIVE OF DIRECT AND INDIRECT LOSSES. INCLUDES SOME EFFECT OF 1927 FLOOD.

** AREA FLOODED BY FLOOD HAVING 0.1 PERCENT CHANCE OF OCCURRENCE.

16. FLOOD PROTECTION BENEFITS. - A substantial portion of potential flood losses can be prevented by construction of flood control works. The amount of such losses prevented represents savings, and these, together with the increases in property values that result from the assurance of protection, determine benefits which form the economic justification for protective works. Average annual direct benefits are the annual direct losses prevented. They were computed as the difference in direct losses under present conditions and under conditions as modified by proposed protective works. Indirect benefits were computed in a similar manner. Benefits from increases in property value are based upon (1) restoring the depreciated value of real estate to its former level and (2) increasing or enhancing the value of land, where development has been retarded by floods, to a level commensurate with its natural utility when unaffected by floods. Restoration benefits accrue, from recovery of depreciation losses, as a result of any complete protection which will eliminate the depressing influences that caused the recent decline and threaten the future of the property. Annual restoration benefits were computed from depreciation losses in proportion to the value of property receiving complete protection. Besides restoring the value of land and buildings to the level which existed prior to the recent extraordinary floods, complete protection will permit more productive use of certain partially developed lands, and as a result their value will be further increased. Annual enhancement benefits were computed from conservative estimates of the net increase in land value, assuming an average return of 5 percent throughout the life of the protective works. Determinable benefits are described in further detail in Section 2 of the Appendix, and they are summarized in paragraph 44 for the recommended plan of protection. Population in the Connecticut River Valley has increased approximately 62 percent in the last thirty years. The further normal

development of the flood plain will result in an increase in future direct and indirect losses prevented which will amount to at least 13.6 percent at the middle of the assumed 50-year life of the protective works. This increase was estimated from projection of present trends of population and valuation in the principal cities and towns of the watershed, making allowance for the decline in the birth rate, and immigration, and various changes in economic and other conditions. Other important benefits will result from the prevention of innumerable losses which have not and cannot be evaluated. Loss of life is an important one of these, for there have been 28 lives lost in the three recent floods, and many more in earlier floods. There are also serious adverse effects upon the lives and security of people and communities concerned, such as mental and physical strain, hardship, inconvenience, and impairment of public health, that are of outstanding importance owing to recent flood experiences. These elements of uncertainty determine the utilization, desirability, and future growth of the area and form an additional justification for protective works in an area as important as the Connecticut River Basin.

V. IMPROVEMENT DESIRED

17. PUBLIC HEARINGS. - Five public hearings were held in different sections of the Connecticut River Basin in connection with this report. The locales, the dates of, and the portions of the Basin covered by these hearings were:

Locale	Date	Covering portion of basin in
Athol, Mass.	December 20, 1938	Massachusetts east of the Connecticut River
Springfield, Mass.	January 9, 1939	Massachusetts west of the Connecticut River
Hartford, Conn.	January 11, 1939	Connecticut
Bellows Falls, Vt.	January 17, 1939	Vermont
Keene, N. H.	January 18, 1939	New Hampshire

Approximately 500 people attended these hearings, representing most of the affected cities, towns, and industries. Various state and railroad officials were also present. Records of these hearings are attached as inclosures to this report. As a result of these hearings it appeared that:

a. The recurrence of disastrous floods has resulted in untold suffering and distress, and has seriously jeopardized the continued industrial livelihood of many areas.

b. The need and desire for flood control is urgent.

c. Reasonable cooperation by local agencies is probable.

18. PROTECTION. - The improvement desired is that which will provide protection against repeated inundations of homes, lands, industries, and utilities, with their attendant loss of life, direct damage, disruption of normal activities, loss of employment, additional expense, depression in values, and threat to communal stability and social security. As the losses over a long period of time have been widely spread throughout the valley, somewhat in proportion to industrial and social development, the

protective works should provide protection to all parts of the valley to the extent practicable and justified.

19. MEASURES ADVOCATED. - The larger, thickly populated, highly developed, and highly industrialized centers have looked first to levees and desire the complete protection afforded by them. The enlargement of the channels of the main river and some tributaries has been advocated at several localities where narrows or other obstructions exist. A channel improvement between Middletown and Hartford to benefit Hartford and vicinity on the main river has been suggested. The construction of reservoirs to detain flood waters in the upper reaches of the valley and release them in such a manner as to reduce substantially flood flows and stages was also advocated. A balanced and interrelated system of reservoirs and levees or other types of local works was indicated as necessary for the basin as a whole, and the proper basis for a comprehensive plan of flood control.

20. POWER. - No urgent need for additional power generating facilities in the Connecticut Valley at the present time was brought out in connection with this investigation. Storage to increase river flow during dry seasons would provide substantial benefits, and has been considered.

21. CONSERVATION FOR RECREATION AND WILD LIFE. - Local interests have stated that water areas for recreation have a high value, and have requested the provision of storage for this purpose at some flood control dams. No urgent need exists for added facilities to benefit wild life, and no request for such consideration has been made.

22. POLLUTION ABATEMENT. - Recent years have seen rapid strides in pollution abatement in the Connecticut River Watershed. Use of many of the streams for public water supply, however, must await further improvements. The states recognize the Connecticut River and tributaries

as recreational assets, proportional in value to their cleanliness. While pollution has but rarely created nuisance conditions, the amount of untreated wastes still being discharged is detrimental to such recreational uses as boating, camping, and fishing, and renders the waters dangerous for drinking and bathing purposes. Need for betterment is shown by the widespread use of the streams for bathing despite health department bans. Improvements in the quality of the waters due to the operation of newly-installed treatment plants are evidenced by a lessening of complaints and by the gradual return of the once-famous shad-fishing industry to the lower Connecticut Valley. In the recreational areas of the northern portion of the watershed, complete elimination of pollution is desired. Sewage-disposal plants now operating or under construction generally provide for only partial purification of wastes. It is desired by the state health departments that eventually complete treatment be given and provisions for the necessary additional equipment are being included in plans for works now in process. Section 3 of the Appendix describes the general sanitary conditions along the various streams in the Connecticut River Watershed; lists the sources, types, and quantities of polluting substances; and outlines the remedial measures now in operation, under construction, or contemplated.

VI. SURVEYS

23. PROFILES. - The elevation of high-water marks for the flood of September 1938 were determined for all the principal tributaries south of and including the West and Ashuelot Rivers, and on the main river south of Windsor, Vermont. A low-water profile of the Deerfield River and its principal tributaries was determined to supplement the profiles which had been determined in connection with prior reports. The profiles and high-water marks for the main river are shown on Plates Nos. 117 to 119 inclusive, Section 8 of the Appendix, and for all the principal tributaries on Plates Nos. 120 to 132 inclusive, Section 8 of the Appendix.

24. SURFACE INVESTIGATIONS. - Twelve potential dam and reservoir sites were considered in addition to the large number of sites studied in connection with prior reports. Sites included in House Document No. 455 were restudied. Plane table surveys of eleven of these sites were made on a scale of either 1:1200 or 1:2400, with vertical intervals of five feet. Where necessary, the reservoir areas were cross-sectioned, with stadia traverse control, to supplement existing reliable topographic data on these areas. Reservoir area sections were also taken at the Claremont site. Surveys for the Barre Falls site in the headwaters of the Chicopee River, including certain geological investigations and hydrological data, were furnished by the Metropolitan District Water Supply Commission of the Commonwealth of Massachusetts. Plane table surveys were also made at eight localities where local protection work was considered most likely to be justified. During 1936 and 1937, by arrangement with the Air Corps, U. S. Army, airplane photographs were made of 23 prospective reservoir areas in the Connecticut Watershed and of the main valley of the Connecticut River from its mouth to Hartford, Connecticut, all at an approximate scale of 1:10,000. Similarly, airplane photographs were made in 1939,

covering large additional areas in the Connecticut Watershed, including many other prospective reservoir areas, at an approximate scale of 1:12,000. These latter photographs are not yet available for use, as the laboratory work of developing and printing the negatives has not been completed by the Air Corps.

25. SUBSURFACE INVESTIGATIONS. - Geologic investigations, including borings, test pits, electrical seismograph, and reconnaissance have been conducted at numerous dam and levee sites since submission of the report printed as House Document No. 455, Seventy-fifth Congress, second session. Six dam sites have been investigated in detail for design and construction purposes. In addition five other dam sites have been further investigated, and explorations have been completed for three channel improvement projects. Studies of foundation conditions and available construction materials have been made for levee and flood wall constructions located at seven widely separated communities. Preliminary subsurface investigations for similar flood protection have been completed at five other locations. The large number of samples obtained through these explorations have been tested by the District Soils Laboratory.

VII. PLAN OF IMPROVEMENT

Power

26. EXISTING HYDROELECTRIC DEVELOPMENTS. - There are 59 active hydroelectric plants in the Connecticut River Basin producing power for sale. They are listed in Table XXXII, Section 4 of the Appendix. The aggregate installed capacity of these plants is about 456,000 kilowatts, or approximately two-thirds of the total hydroelectric plant capacity of the zone comprising the New England States, exclusive of Maine. The larger part of the output of these hydroelectric plants is controlled by the New England Power Association and is operated as a unified system with the larger steam plants of this Association and of the Boston Edison Company. About 296,000 kilowatts of the above-mentioned capacity are located at stations on the main stem of the Connecticut River, and about 99,000 kilowatts are located on the Deerfield River. Smaller plants and numerous industrial plants are located on uncontrolled tributaries of the Connecticut River. There has been a general increase in the power production in the zone, except during the three years immediately following 1929. The most recent hydroelectric developments in the zone are the Frank D. Comerford station, on the Connecticut River at Lower Fifteen Mile Falls, in the upper Connecticut River Basin, and the McIndoe Falls plant, an equalizing plant just below the Comerford station. Since the construction of these stations, steam generating capacity has been installed within the zone, and the construction of an additional steam generating unit of 40,000 kilowatts in Providence, Rhode Island, is pending. Because of the nature of recent power developments in the zone, and of the plans for additional capacity in the immediate future, there is no assured market at present for additional power from hydroelectric stations.

27. POSSIBLE FUTURE HYDROELECTRIC DEVELOPMENTS. - The most economical and easily improved sites for water power in the basin have been developed. Consideration has been given by the New England Power Association to the development of a large hydroelectric plant at upper Fifteen Mile Falls, a few miles above the existing lower Fifteen Mile Falls plant. The only possible water-power sites on the main river below the mouth of the Passumpsic River that have not been developed are at Piermont and Hart Island. There are three existing plants on the main river, namely, at Ryegate, Wilder, and Enfield, that do not have equipment of sufficient capacity to utilize additional flows. Until these plants are redeveloped, no appreciable benefits to them can be realized from future storage reservoirs. On several tributaries of the Connecticut River, there are attractive natural sites for the development of new power stations, but on account of their comparatively small drainage areas and wide variation in natural flows, many of these sites will probably never be developed. Some of them, however, may become justified after storage reservoirs have been constructed and the flows partially regulated. In considering possible future benefits from upstream storage, in the following paragraphs, the following developments were included:

Redevelopment

Plant	River	Head, feet
Wilder, N. H.	Connecticut	35
Holyoke, Mass.	Connecticut	55
Enfield, Conn.	Connecticut	28
West Dummerston, Vt.	West	52

New development

Plant	River	Head, in feet
Piermont, N. H.	Connecticut	28
Hart Island, N. H.	Connecticut	26
Sharon, Vt.	White	57
West Hartford, Vt.	White	35
Hartford, Vt.	White	42
Brattleboro, Vt.	West	58

Additional data on these plants are given in Table XXXIII, Section 4, of the Appendix.

28. POSSIBLE POWER PLANTS AT FLOOD CONTROL DAMS. - Studies were made of the feasibility of developing power at each of the flood control dam sites, in accordance with the provisions of Section 4 of the Flood Control Act of 1938. In general, the development of power at flood control sites is not economically feasible. There are many sites in the basin physically adaptable to power development which are not desirable for flood control because the storage capacity available is either very small or prohibitively expensive. In general, an attractive power site is one in a steep section of the river where a high head may be obtained without flooding excessive land areas in the reservoir. The requirement for flood control is a large basin where a low inexpensive dam will enable the storage of a great volume of water. It was found that the development of power in conjunction with flood control storage is economically feasible at present at only three of the flood control sites considered: Upper Fifteen Mile Falls, New Hampshire; Gaysville, Vermont; and Williamsville, Vermont. No assured market for power is available at present, however, and for this reason immediate construction of dual-purpose reservoirs at these three sites is not recommended. The dams at Gaysville and Williamsville can be built so that they may be raised at a future date to provide facilities for the development of power

at such time as a market develops. In the case of the Upper Fifteen Mile Falls dam, it is proposed to build it initially to its ultimate height, and reserve the entire capacity for flood control until such time as it is feasible to install hydroelectric generating equipment and utilize a portion of the capacity for power. Upon the recommendation of the Federal Power Commission for additional capacity, plans for flood control dams at Knightville, Massachusetts, and Union Village, Vermont, have been altered to provide dams 10 feet higher than those recommended for flood control. The dams will be built to this higher elevation, and, at such time as is feasible, the increment of capacity thus provided will be utilized for power development. In further compliance with recommendations of the Federal Power Commission, designs for the Tully dam have been altered to permit of future raising of the dam, in order to make possible power generation in addition to flood control. Pertinent data for the Upper Fifteen Mile Falls, Gaysville, and Williamsville sites, selected for ultimate power development, are shown in Table IV. Pertinent information regarding the possible development of power at all of the flood control sites is given in Table XXXIV, Section 4, of the Appendix. The cost of storage shown chargeable to power is only the extra cost of providing the increased reservoir capacity necessary, and in every case is less than the cost prorated on the basis of storage capacity. Power values of $12.50 per kilowatt for peaking capacity, at the site, and 1.5 mills per kilowatt-hour for energy output were used. A load factor of 25 percent was assumed. Benefits to existing downstream power plants, which would be derived from the usable storage at each power site studied, were credited to each site.

TABLE IV

PERTINENT DATA - COMBINED FLOOD CONTROL AND POWER RESERVOIRS

Reservoir	Upper Fifteen Mile Falls	Gaysville	Williams-ville
Drainage area in square miles	1,626	226	400
Flood control capacity:			
Inches	3.0	7.0	7.0
Acre-feet	260,000	84,300	150,000
Power capacity:			
Inches	2.5	3.3	4.8
Acre-feet	216,000	40,000	103,000
Total capacity:			
Inches	5.5	10.3	11.8
Acre-feet	476,000	124,300	253,000
Maximum power pool elevation in feet above mean sea level	806	767	460
Spillway crest elevation in feet above mean sea level	851	817	509
Area of maximum power pool in acres	3,500	1,090	2,330
Area of reservoir at spillway crest in acres	12,800	2,240	3,8[illegible]
Average power head in feet	150	170	114
Minimum regulated flow in cubic feet per second	1,290	170	280
Installed capacity in kilowatts	125,000	8,000	9,000
Average annual energy output in kilowatt-hours	256,000,000	32,200,000	38,000,000
Cost of flood control:			
Total	$10,590,000	$4,080,000	$5,960,000
Annual	563,000	224,900	308,600
Cost of power storage increment:			
Total	4,245,000	1,225,000	1,772,000
Annual	201,000	70,000	105,000
Cost of power installation:			
Total	9,480,000	1,300,000	648,000
Annual	753,000	87,700	55,300
Total cost chargeable to power:			
Total	13,725,000	2,525,000	2,420,000
Annual	954,000	157,700	160,300
Annual value of peaking capacity and output at site	1,946,500	147,800	166,000
Annual benefit to existing downstream plants	204,300	26,800	18,900
Total annual power value	2,150,800	174,600	184,900

29. EXISTING STORAGE DEVELOPMENTS. - There is a large amount of storage capacity now available upstream from the major hydroelectric developments in the Connecticut River Basin. The principal storage in the headwaters of the Connecticut River is at the upper Connecticut Lakes and the Pittsburg Reservoir. There are also 33,000 acre-feet of usable storage at the Lower Fifteen Mile Falls development. Storage exists on the upper Deerfield River at Somerset and Harriman Reservoirs. Other storage in the watershed is in lesser amounts or is reserved for municipal water supply. Existing storage within the basin is given in Table V.

TABLE V. EXISTING STORAGE RESERVOIRS

Reservoir	River	Drainage area, Square miles	Storage, Acre-feet
Upper Connecticut Lakes	Connecticut	83	88,300
Pittsburg	do	89 net	96,500
Lower Fifteen Mile Falls	do	1478 net	33,000
Grafton Pond, Goose Pond, Crystal and Mascoma Lakes	Mascoma	153	28,800
Sunapee Lake	Sugar	45	19,800
Somerset and Harriman	Deerfield	184	178,000
Quabbin	Swift and Ware (Chicopee)	186	1,273,[illegible]00
Cobble Mountain	Westfield	45	70,000
Otis, Compensation, Nepaug, and Barkhamsted	Farmington	112	148,600
Total		2375	1,936,2[illegible]

The existing power developments have pondage in various amounts, but their effect upon flood flows cannot be established. The reservoirs on the Mascoma and the Sugar Rivers are natural lakes of relatively small capacity, and are of but little value for regulating or increasing the low-water flow below the reservoirs. The Swift, Westfield, and Farmington River reservoirs are primarily for water supply, and are of no material benefit to any water powers. The upper Connecticut

Lakes reservoirs were constructed and are operated by private interests for the benefit of the power plants on the Connecticut River. During the dry seasons of the year the low-water flow is increased by their storage about 600 cubic feet per second. The Pittsburg reservoir is estimated to increase minimum flows in the Connecticut River by 700 cubic feet per second. The Harriman and Somerset Reservoirs, on the Deerfield River, which were constructed and are operated by the New England Power Association, increase the low-water flows of the Deerfield River and of the Connecticut River below Greenfield by varying amounts up to 600 cubic feet per second.

30. POSSIBLE CONSERVATION STORAGE AT FLOOD CONTROL DAMS. - All of the flood control sites investigated in detail were studied to ascertain the benefits to be derived from additional conservation storage capacity, both on the basis of existing downstream utilization and possible future development. In accordance with existing law, local interests may obtain conservation storage at flood control dams by paying the extra costs involved in providing the additional storage. Existing storage, as listed in Table V, yields substantial benefits to existing power developments, notably on the Connecticut and Deerfield Rivers. Initial units of conservation storage produce the greatest benefit, and subsequent increments do not have the same high value. In computing the benefits to be credited and the costs to be charged to conservation storage at flood control sites, liberal assumptions were made to show maximum benefits to conservation storage. It was assumed that increases of minimum discharge could be utilized at all utility plants at a load factor of 25 percent, and that increased peaking capacity thus made possible would have a value of $6 per kilowatt. In every case involved, the realization of additional peaking capacity would require the installation of additional generating capacity at existing stations. Additional

output at existing utility plants, derived from stored water, was evaluated at 1.5 mills per kilowatt-hour. Once-a-year use of 100 percent of the stored water was assumed. The cost of the storage shown chargeable to power is only the extra cost of providing the increased reservoir capacity necessary, and is in every case less than the cost prorated on the basis of storage capacity. Data concerning the possible value of conservation storage at all flood control sites are given in Table XXXV, Section 4, of the Appendix.

a. Storage justified for immediate development. - On the basis of benefits to existing water power developments, conservation storage in addition to flood control storage is economically justified at three sites; West Canaan, New Hampshire; Ludlow, Vermont; and Victory, Vermont. Pertinent information about these proposed dams and reservoirs is given in Table VI. Conservation storage capacities at West Canaan and Ludlow are limited by physical features, and at Victory by consideration of normal run-off conditions.

b. Storage justified for future development. - Conservation storage in addition to flood control storage will be justified at South Branch, Vermont, at such time as possible future power installations within the basin are constructed. Because the benefits to existing plants are not sufficient to justify the construction of the storage at the present time, and since the future construction of additional power stations is uncertain, additional storage at this site is not recommended at this time. The plans for the flood control dam, however, have been altered in such fashion as to permit of eventual future raising of the dam when additional power installations make it attractive to do so. Table VI gives pertinent data for this site. The feasible conservation storage capacity at the site is limited by physical features.

TABLE VI
POWER CONSERVATION STORAGE

Reservoir	Victory	W. Canaan	Ludlow	So. Branch
Damage area in square miles	66	80	56	45
Flood control capacity:				
Inches	8.0	8.0	8.0	7.0
Acre-feet	23,200	34,100	23,900	16,800
Conservation capacity:				
Inches	15.0	4.5	10.0	10.0
Acre-feet	52,800	19,400	30,100	24,200
Total Capacity:				
Inches	23.0	12.5	18.0	17.0
Acre-feet	81,000	53,500	54,000	41,000
Conservation pool level in feet above mean sea level	1,164	888	1,074	826
Spillway crest elevation in feet above mean sea level	1,175	910	1,090	844
Area of conservation pool in acres	2,300	1,220	1,200	700
Area of reservoir at spillway crest in acres	2,830	1,900	1,600	950
Increase in minimum flow in cubic feet per second	94	29	66	53
Average existing head through which utilized in feet	254	266	302	-
Average ultimate head through which utilized in feet	-	-	-	405
Increased peaking capacity in kilowatts	6,200	2,110	5,620	5,920
Increased annual output in kilowatt-hours	11,080,000	4,250,000	7,490,000	8,080,000
Total annual value of increased peaking capacity and output	$53,300	$19,000	$45,000	$47,600
Cost of flood control				
Total	1,023,000	2,240,000	1,741,000	1,270,000
Annual	60,100	114,600	97,100	70,600
Cost of conservation				
Total	392,000	280,000	459,000	832,000
Annual	20,100	13,800	26,900	38,700
Total cost				
Total	1,415,000	2,520,000	2,200,000	2,102,000
Annual	80,200	128,400	124,000	109,300

31. RECREATION. - The entire watershed of the Connecticut River is spotted with lakes and ponds which are widely used for recreation and have a high value for this purpose. There is no urgent local need for more facilities of a similar nature. Additional lakes would undoubtedly bring an increment of revenue to the localities, derived from increased tourist trade, but since existing facilities are sufficient for the basic needs, the local interests deriving the increased income should contribute the extra cost of providing any recreational storage which they desire. This type of local participation is in accordance with existing law, namely Section 5 of Public 738, 74th Congress (1936 Flood Control Act) as amended by the Act of July 19, 1937, and is to be encouraged. State officials of Massachusetts have requested that 4000 acre-feet of conservation storage be provided at Lower Naukeag site, and 8000 acre-feet at Barre Falls site, with the understanding that Massachusetts assume the cost of each reservoir over and above the cost for the selected flood control capacity. They have stated that the value of the additional storage is worth the estimated cost to the state, but that final action on this must be by the State Legislature. Table VII gives pertinent data concerning the two reservoirs if conservation is provided.

(Table VII on following page)

TABLE VII

CONSERVATION STORAGE

Reservoir	Barre Falls	Lower Naukeag
Drainage area in square miles	57	20
Conservation capacity:		
Inches	2.6	3.7
Acre-feet	8,000	4,000
Flood control capacity:		
Inches	8.0	8.0
Acre-feet	24,300	8,530
Total capacity:		
Inches	10.6	11.7
Acre-feet	32,300	12,530
Conservation pool level in feet above mean sea level	802.0	1,071.0
Spillway crest elevation in feet above mean sea level	811.0	1,079.0
Conservation pool area in acres	550	830
Mean depth of conservation pool in feet	9.4	5.0
Area at spillway crest in acres	1,850	1,160
Cost of conservation:		
Total	$157,000	$112,000
Annual	8,100	5,000
Cost of flood control:		
Total	965,000	548,000
Annual	53,000	34,400
Total cost:		
Total	1,122,000	660,000
Annual	61,100	39,400

Additional storage for conservation may be provided at other sites, if local interests request and pay the cost of the additional storage in accordance with the statute referred to in this paragraph.

32. WILD LIFE. - The many existing natural lakes and ponds provide ample haven for all species of wild life, and no special features for this purpose are provided at proposed flood control reservoirs. It is expected that the flood control reservoirs will have a beneficial effect upon fish life, by preventing the ruthless swooping out of fish during major floods. The relatively quiet waters stored in the flood control reservoirs will enable the fish to remain in the section of river natural to them. In the case of conservation storage pools, these will offer protection for fish in winter, and obviate the necessity of long migrations of the fish to find deep water.

33. PRESENT CONDITIONS. - The Connecticut River Watershed, as compared with other nearby drainage basins, is in relatively good sanitary condition in the upper portion of the watershed in New Hampshire and Vermont. Here the streams are generally capable of accommodating the pollutional load because of the low population densities and the ample opportunity for self-purification. In the Massachusetts and Connecticut portions of the watershed, where the density of population is eight times as great, the problem is more acute. Since the trade wastes discharged into the waterways are from varied industries and are generally dilute, the problem of pollution abatement in the Connecticut River Basin resolves itself chiefly into the treatment of domestic wastes from the numerous sewered communities in the lower watershed. During the last decade there has been a significant increase in the volume of wastes receiving treatment, so that at present over 36 percent is treated. Upon completion of sewage-disposal plants now proposed or under construction, less than half of the wastes will remain untreated. The two most important developments in the abatement of Connecticut River pollution are (1) the completion of the treatment plant serving the Hartford Metropolitan Sewerage District, and (2) construction of two disposal plants to treat wastes from the vicinity of Springfield, Massachusetts. Reference to Plate 13 of the Appendix shows that relatively few of the larger cities and towns continue to discharge untreated sewage into the streams.

34. POLLUTION ABATEMENT PLANS. - There is a growing demand for complete eradication of pollution on most of the streams of the Connecticut River Watershed. Recreational needs of the upper

watershed require not only that establishment of new pollution sources be avoided, but also that existing contamination be entirely removed as soon as practicable. In other watersheds, state health departments would be satisfied if objectionable nuisances could be averted through provision of adequate low-water flow, but here removal, not mere dilution, of wastes is desired. In Connecticut, where the State Water Commission is empowered to order and enforce the construction of treatment plants when needed, the greatest sources of pollution have been remedied. In Massachusetts, despite lack of an enforceable statute, civic pride has resulted in marked improvements. There are, however, major pollutional sources still in existence in Northampton, Holyoke, and Chicopee, Massachusetts. Plans for these cities have been completed, but no active progress in initiating the necessary construction programs has taken place. While no formal agreements have been entered into by the states concerned, the results of their cooperative efforts are evident.

35. EFFECT OF FLOOD CONTROL RESERVOIRS ON WATER AY POLLUTION.- The operation of storage reservoirs for the purpose of reducing flood discharges will provide valuable sanitation benefits. More fully described in the Appendix, Section 3 on "Pollution", these include (1) protection of sewage-treatment plants, (2) diminution of pollution load picked up by high flood stages, (3) sedimentation in storage basins, (4) aeration at outlet structures, (5) more effective stream flushing, and (6) benefits to water supplies.

36. SITES STUDIED. - The investigations for this report were greatly simplified by previous studies made for the reports printed as House Document No. 412, Seventy-fourth Congress, second session and House Document No. 455, Seventy-fifth Congress, second session. The latter report recommended a Comprehensive Plan for flood control that included 20 storage reservoirs and 10 alternates. This report proposes certain changes in the Comprehensive Plan occasioned by the additional information secured as a result of the flood of September 1938. Further studies were made of the reservoirs included in the Comprehensive Plan of House Document No. 455, of additional reservoirs investigated but not recommended as part of that Comprehensive Plan, and of a few new sites. Some sites were rejected after preliminary investigations revealed that dams at these sites obviously could not be justified, or that they were inferior to alternate sites controlling the same or similar watershed areas. Table VIII lists the 55 sites for which more intensive studies were made.

(See Table VIII on following page)

TABLE VIII

LIST OF SITES STUDIED
(In downstream order)

Name of site	Stream	Drainage area above site in square miles
Upper Fifteen Mile Falls*	Connecticut River, Vt. & N. H.	1,626
East Haven	Passumpsic River, Vt.	48
Lyndonville*	Passumpsic River, Vt.	70
Lyndon Center	Millers Run (Passumpsic River), Vt.	46
Victory*	Moose River (Passumpsic River), Vt.	66
Harvey Lake	Stevens River, Vt.	21
Bethlehem Junction	Ammonoosuc River, N. H.	90
Franconia	Ham Branch, Gale River (Ammonoosuc River), N. H.	30
Gale River	Gale River (Ammonoosuc River), N. H.	86
Sugar Hill*	Ammonoosuc River, N. H.	246
Bath	Ammonoosuc River, N. H.	397
Groton Pond	Wells River, Vt.	17
South Branch*	South Branch (Waits River), Vt.	45
Union Village*	Ompompanoosuc River, Vt.	126
Gaysville*	White River, Vt.	226
Ayers Brook*	Ayers Brook, Third Branch (White R.), Vt.	30
South Randolph*	Second Branch (White River), Vt.	63
South Tunbridge*	First Branch (White River), Vt.	102
Centerville	White River, Vt.	692
West Canaan*	Mascoma River, N. H.	80
Mascoma Lake	Mascoma River, N. H.	153
Bridgewater Corners	Ottauquechee River, Vt.	101
North Hartland*	Ottauquechee River, Vt.	222
Stocker Pond	Stocker Brook, Croydon Branch (Sugar River), N. H.	35
Croydon	Croydon Branch (Sugar River), N. H.	55

TABLE VIII (Cont'd.)

Name of site	Stream	Drainage area above site in square miles
Claremont*	Sugar River, N. H.	245
Ludlow*	Black River, Vt.	56
Perkinsville	Black River, Vt.	142
Amsden	North Branch (Black River), Vt.	27
North Springfield*	Black River, Vt.	158
Brockway*	Williams River, Vt.	101
Cambridgeport*	Saxtons River, Vt.	58
Holden	Cold River, N. H.	57
The Island	West River, Vt.	41
North Landgrove	Orcutt Brook (West River), Vt.	21
Newfane	West River, Vt.	326
Williamsville*	West River, Vt.	400
Surry Mountain*	Ashuelot River, N. H.	100
Otter Brook*	Otter Brook (Ashuelot River), N. H.	47
Honey Hill*	South Branch (Ashuelot River), N. H.	70
Lower Naukeag*	Millers River, Mass.	20
Lake Monomonac	Millers River, Mass.	19
Priest Pond	Priest Brook (Millers River), Mass.	19
Hamlet	Otter River (Millers River), Mass.	37
Birch Hill*	Millers River, Mass.	175
Tully*	Tully River (Millers River), Mass.	50
Fort Morrison*	North River (Deerfield River), Mass.	48
Shattuckville	North River (Deerfield River), Mass.	89
Greenfield	Green River (Deerfield River), Mass.	72
Easthampton*	Manhan River, Mass.	68
Barre Falls*	Ware River (Chicopee River), Mass.	57
Thorndike	Ware River (Chicopee River), Mass.	214
West Brookfield*	Quaboag River (Chicopee River), Mass.	106
Knightville*	Westfield River, Mass.	164
Riverton	Farmington River, Conn.	130

*Included in the Revised Comprehensive Plan.

37. GENERAL LOCATION OF RESERVOIRS. - Flood damages have not been severe in the Connecticut Basin above the mouth of the White River. Run-off from this area does, however, contribute to flood peak discharges on the lower main river. Consequently, it is essential that control be provided over as large an area as possible. The extensive development of the main river valley precludes the location of flood control reservoirs on the main stem of the Connecticut River below Lower Fifteen Mile Falls. A dam and reservoir at the Upper Fifteen Mile Falls site would adequately control the run-off from the entire contributing area. Run-off from the area below the watershed of the Farmington River has a negligible effect upon flood stages in the main valley. The selection of additional sites for the flood control reservoirs studied has been limited, therefore, to the tributaries between Upper Fifteen Mile Falls and the Farmington River, inclusive. On tributaries which are extensively developed, sites in the upper reaches have been selected to provide maximum benefits to communities along the tributaries as well as to points on the main river. On the less developed tributaries, reservoirs are often located near the mouths, to control maximum drainage areas for the benefit of damage centers on the main stem.

38. BASIS OF INDIVIDUAL RESERVOIR CAPACITY. - The most economical reservoir capacity for each site was determined as the capacity for which the greatest annual flood-protection benefits in proportion to the annual charges are obtained, except that a minimum storage capacity equivalent to 6.0 inches of run-off from the drainage area above each reservoir is considered necessary to provide an effective degree of protection to downstream damage

centers. Therefore, all proposed reservoirs with the exception of two which have already been designed and Upper Fifteen Mile Falls have a capacity of 6.0 inches or greater. The selected capacities and other pertinent data for the 29 reservoirs included in the Revised Comprehensive Plan hereinafter proposed are shown in Table IX.

(Table IX on following page)

TABLE IX
RESERVOIR DATA

NAME OF RESERVOIR	STREAM	DRAINAGE AREA IN SQUARE MILES: NET	DRAINAGE AREA IN SQUARE MILES: GROSS	% OF TOTAL CONNECTICUT RIVER DRAINAGE AREA CONTROLLED	FLOOD CONTROL CAPACITY INCHES OF RUN-OFF: NET AREA	FLOOD CONTROL CAPACITY INCHES OF RUN-OFF: GROSS AREA	ACRE-FEET	SPILLWAY ELEVATION IN FEET ABOVE M.S.L.***	AREA FLOODED AT SPILLWAY CREST IN ACRES	HEIGHT OF DAM IN FEET
MASSACHUSETTS										
KNIGHTVILLE	WESTFIELD RIVER, MASS.	164	164	1.46	4.5	4.5	39,300	600.0	850	160
EASTHAMPTON	MANHAN RIVER, MASS.	68	68	0.60	6.0	6.0	21,800	167.0	1,210	66
FORT MORRISON	NORTH RIVER (DEERFIELD RIVER), MASS.	48	48	0.43	6.0	6.0	15,400	711.0	400	113
WEST BROOKFIELD	QUABOAG RIVER (CHICOPEE RIVER), MASS.	106	106	0.94	6.0	6.0	33,900	611.5	4,000	31
BARRE FALLS	WARE RIVER (CHICOPEE RIVER), MASS.	57	57	0.51	8.0	8.0	24,300	815.5*	1,450	63.5
TULLY	TULLY RIVER (MILLERS RIVER), MASS.	50	50	0.44	8.3	8.3	22,150	668.0	1,100	62
BIRCH HILL	MILLERS RIVER, MASS.	155	175	1.38	6.0	5.4	49,900	852.0	3,200	56
LOWER NAUKEAG	MILLERS RIVER, MASS.	20	20	0.18	8.0	8.0	8,530	1,075.5	1,000	30
NEW HAMPSHIRE										
HONEY HILL	SOUTH BRANCH (ASHUELOT RIVER), N. H.	70	70	0.62	7.0	7.0	26,200	520.0	1,360	65
OTTER BROOK	OTTER BROOK (ASHUELOT RIVER), N. H.	47	47	0.42	7.0	7.0	17,500	771.5	350	122.5
SURRY MOUNTAIN	ASHUELOT RIVER, N. H.	100	100	0.89	6.1	6.1	32,500	550.0	970	83
CLAREMONT	SUGAR RIVER, N. H.	245	245	2.18	6.0	6.0	78,400	627.5	1,500	122.5
WEST CANAAN	MASCOMA RIVER, N. H.	80	80	0.71	8.0	8.0	34,100	910.0	1,900	79
SUGAR HILL	AMMONOOSUC RIVER, N. H.	246	246	2.19	7.0	7.0	91,600	739.0	1,750	163
UPPER FIFTEEN MILE FALLS	CONNECTICUT RIVER, VT. & N. H.	1,626	1,626	14.44	5.5	5.5	476,000	851.0	12,800	241
VERMONT										
WILLIAMSVILLE	WEST RIVER, VT.	400	400	3.55	7.0	7.0	150,000	478.0	2,800	172
CAMBRIDGEPORT	SAXTONS RIVER, VT.	58	58	0.52	7.0	7.0	21,600	642.0	630	101
BROCKWAY	WILLIAMS RIVER, VT.	101	101	0.90	6.0	6.0	32,300	552.5	820	132
NORTH SPRINGFIELD	BLACK RIVER, VT.	102	158	0.91	6.2	4.0	33,400	528.5	960	106
LUDLOW	BLACK RIVER, VT.	56	56	0.50	8.0	8.0	23,900	1,090.0	1,690	118
NORTH HARTLAND	OTTAUQUECHEE RIVER, VT.	222	222	1.97	6.0	6.0	71,100	546.5	1,120	176
SOUTH TUNBRIDGE	FIRST BRANCH (WHITE RIVER), VT.	102	102	0.91	6.0	6.0	32,600	564.0	860	105
SOUTH RANDOLPH	SECOND BRANCH (WHITE RIVER), VT.	63	63	0.56	7.0	7.0	23,500	596.5	630	94
AYERS BROOK	AYERS BROOK, THIRD BRANCH (WHITE RIVER), VT.	30	30	0.27	7.0	7.0	11,200	697.5	610	75.5
GAYSVILLE	WHITE RIVER, VT.	226	226	2.01	7.0	7.0	84,300	798.0	1,860	173**
UNION VILLAGE	OMPOMPANOOSUC RIVER, VT.	126	126	1.12	4.5	4.5	30,200	554.0	650	170
SOUTH BRANCH	SOUTH BRANCH (WAITS RIVER), VT.	45	45	0.40	7.0	7.0	16,800	815.0	570	108
VICTORY	MOOSE RIVER (PASSUMPSIC RIVER), VT.	66	66	0.59	8.0	8.0	23,200	1,175.0	2,830	75
LYNDONVILLE	PASSUMPSIC RIVER, VT.	70	70	0.62	7.0	7.0	26,100	844.0	600	130
TOTAL		4749		42.22			1,556,780			

* METROPOLITAN DISTRICT WATER SUPPLY COMMISSION DATUM.

** TOP OF CONCRETE ARCH.

*** ELEVATIONS AS RECOMMENDED FOR INITIAL CONSTRUCTION.

39. BASIS OF SELECTION OF RESERVOIRS. - The reservoirs of the Revised Comprehensive Plan were selected to provide the most effective flood protection practicable, due consideration having been given to the sites available and the economics involved. Consideration was given to the relative economic values of the individual reservoirs; to the control of the amount of watershed area desired; to the geographical distribution of reservoirs to obtain dependable reduction of flood stages at all damage centers during storms of all probable types, distributions, and magnitudes; and to the effect of existing partial control where large storage reservoirs provide partial protection to limited areas.

40. RESERVOIRS FOR REVISED COMPREHENSIVE PLAN. - Based on the above considerations, 29 reservoirs have been selected for inclusion in the Revised Comprehensive Plan. These reservoirs most satisfactorily fulfill the requirements within the range of economic justification. Pertinent data regarding these reservoirs have already been given in Table IX. The total effective flood-storage capacity of the 29 reservoirs is 1,556,780 acre-feet. The total drainage area controlled is 4,749 square miles, or 42 percent of the entire Connecticut River Watershed. One of the dams is located on the main stem and controls 1,626 square miles in Vermont, New Hampshire, and Canada. Fourteen of the dams are located in Vermont and control 1,667 square miles; six are located in New Hampshire and control 788 square miles; eight are located in Massachusetts and control 668 square miles. The 28 reservoirs distributed among 18 tributary watersheds of the Connecticut River are located as follows: four reservoirs on the White River Watershed; three each on the Ashuelot and Millers; two each on the

Passumpsic, Black, and Chicopee; and one each on the Ammonoosuc, Waits, Ompompanoosuc, Mascoma, Ottauquechee, Sugar, Williams, Saxtons, West, Deerfield, Manhan, and Westfield. On 14 watersheds, 24 of the reservoirs will provide extensive local protection as well as protection downstream on the Connecticut River. Five reservoirs located near the mouths of tributaries will afford protection to points on the Connecticut River only. The locations of the reservoirs and the drainage areas controlled are shown on Plate No. 1; their elevations are indicated on the profiles on Plates Nos. 119 to 132, inclusive, Section 8 of the Appendix. The estimated total cost of the 29 reservoirs for flood control alone is $80,291,000.

41. DRAINAGE AREA CONTROLLED. - The percentage of drainage area controlled by each reservoir, as shown in Table IX, is based upon the entire drainage area of the Connecticut River Watershed. In Table X, the percentages of drainage area controlled by all the flood control reservoirs of the proposed Revised Comprehensive Plan are shown. The percentage of control for each tributary and the progressive control attained as each tributary joins the main river are indicated.

(Table X on following page)

TABLE X

SUMMARY OF DRAINAGE AREAS CONTROLLED BY THE RESERVOIRS OF THE REVISED COMPREHENSIVE PLAN

RIVER	Drainage Area		Controlled drainage area above dam site		Ratio of controlled drainage area to total drainage area	
	Tributary	Main river including tributary	Tributary	Cumulative	Tributary	Main river
	Square miles	Square miles	Square miles	Square miles	Percent	Percent
Connecticut above Upper Fifteen Mile Falls	--	1,626	1,626	1,626	--	100.0
Passumpsic	507	2,158	136	1,762	26.8	81.6
Ammonoosuc	402	2,629	246	2,008	61.2	76.4
Waits	156	3,012	45	2,053	28.8	68.2
Ompompanoosuc	136	3,219	126	2,179	92.6	67.7
White	710	4,068	421	2,600	59.3	63.9
Mascoma	195	4,263	80	2,680	41.0	62.9
Ottauquechee	223	4,525	222	2,902	99.6	64.1
Sugar	274	4,948	245	3,147	89.4	63.6
Black	204	5,231	158	3,305	77.5	63.2
Williams	117	5,301	101	3,406	86.3	63.3
Saxtons	78	5,465	58	3,464	74.4	63.4
West	423	6,167	400	3,864	94.6	62.7
Ashuelot	420	6,647	217	4,081	51.7	61.2
Millers	390	7,131	225	4,306	57.7	60.4
Deerfield	665	7,839	48	4,354	7.2	55.5
Manhan	106	8,261	68	4,422	64.2	53.5
Chicopee	724	9,027	163	4,585	22.5	50.8
Westfield	520	9,595	164	4,749	31.5	49.5
Connecticut at mouth	--	11,260	--	4,749	--	42.2

The area below Hartford, amounting to 617 square miles, has a negligible effect upon the flood losses of the valley, and therefore should be disregarded. Consequently, the total drainage area contributing to flood crests is 10,643 square miles. The reservoirs of the Revised Comprehensive Plan control 4,789 square miles and existing storage reservoirs provide a large measure of control for 599 square miles. The latter storage will not provide dependable protection, as the reservoirs may be full at flood periods so that surcharge storage only would be available for modification of flood flows. With the plan in operation, 45 percent of the watershed above Hartford would be controlled by the reservoirs of the Revised Comprehensive Plan.

42. STAGE REDUCTIONS. - The effect of the Revised Comprehensive Plan in the reduction of flood discharges and stages for floods such as those of March 1936 and September 1938, and for the design and demonstration floods, are shown in Tables XI and XII.

(Tables XI and XII on following pages)

TABLE XI EFFECT OF REVISED COMPREHENSIVE PLAN OF RESERVOIRS UPON THE 1936 & 1938 FLOODS

RIVER	STATION	MARCH 1936 FLOOD						SEPTEMBER 1938 FLOOD					
		EXPERIENCED		MODIFIED		REDUCTION		EXPERIENCED		MODIFIED		REDUCTION	
		STAGE IN FEET	DISCHARGE C.F.S.	STAGE IN FEET	DISCHARGE C.F.S.	STAGE IN FEET	DISCHARGE C.F.S.	STAGE IN FEET	DISCHARGE C.F.S.	STAGE IN FEET	DISCHARGE C.F.S.	STAGE IN FEET	DISCHARGE C.F.S.
PASSUMPSIC	PASSUMPSIC	21.2	16,000	16.9	11,900	4.3	4,100	12.2	7,710	9.8	5,530	2.4	2,130
AMMONOOSUC	BATH	15.4	27,000	11.0	13,700	4.4	14,200	15.1	23,000	9.2	8,850	5.9	17,950
WAITS	MOUTH	—	8,000	—	6,060	—	1,940	—	6,900	—	4,850	—	1,350
OMPOMPANOOSUC	MOUTH	—	7,400	—	3,550	—	3,850	—	5,900	—	480	—	5,420
WHITE	W. HARTFORD	13.9	45,400	15.6	28,500	3.3	16,900	19.3	47,600	14.2	22,900	5.1	24,700
MASCOMA	MASCOMA	7.5	5,840	6.1	3,150	1.4	2,690	6.8	4,400	5.6	2,470	1.2	1,930
OTTAUQUECHEE	N. HARTLAND*	15.6	19,200	—	6,780	—	12,420	17.7	24,400	—	—	—	24,520
SUGAR	W. CLAREMONT	10.9	14,000	5.5	3,670	5.4	10,360	10.5	13,100	3.2	1,020	7.3	12,080
BLACK	N. SPRINGFIELD	16.4	14,700	8.8	4,130	7.6	10,510	17.7	15,500	5.2	1,130	12.5	14,370
SAXTONS	MOUTH	—	5,000	—	1,950	—	3,050	—	5,800	—	1,240	—	4,360
WEST	NEWFANE *	19.3	39,000	—	2,340	—	36,660	22.8	52,300	—	—	—	69,250
ASHUELOT	HINSDALE	20.2#	16,600	9.2	11,400	—	5,200	11.4	16,200	8.6	9,610	2.8	6,590
MILLERS	ERVING	10.9	19,700	8.5	12,790	2.4	6,910	13.4	29,000	10.4	18,300	3.0	10,700
CHICOPEE	BIRCHAM BEND	9.9	20,400	7.8	12,200	2.1	8,200	—	45,200	—	33,500	—	11,700
WESTFIELD	WESTFIELD	27.2	48,200	24.9	40,600	2.3	7,600	29.4	55,500	26.0	44,000	3.4	11,500
CONNECTICUT	S. NEWBURY	38.6	77,800	29.4	68,600	9.2	31,300	28.6	43,700	16.3	19,200	12.3	24,500
CONNECTICUT	WHITE RIVER JCT.	32.5	120,000	24.1	71,500	8.4	48,500	28.7	82,400	19.8	47,900	8.9	34,500
CONNECTICUT	BELLOWS FALLS**	302.2	175,600	291.1	88,500	11.1	86,500	295.2	115,700	284.0	48,300	11.2	67,200
CONNECTICUT	VERNON (H.W.)	130.0	132,000	127.9	83,000	8.1	95,000	132.1	132,500	125.3	57,000	6.8	75,500
CONNECTICUT	VERNON (T.W.)##	—	199,000	—	91,000	—	107,400	—	146,500	—	59,500	—	87,000
CONNECTICUT	MONTAGUE CITY	47.6	236,000	38.0	144,500	9.6	91,500	43.5	195,000	32.2	100,000	11.3	95,000
CONNECTICUT	NORTHAMPTON	129.4	239,000	121.7	144,000	7.7	95,000	126.0	195,000	117.1	100,000	8.9	95,000
CONNECTICUT	HOLYOKE	17.2	244,000	12.5	149,000	4.7	95,000	15.1	197,000	9.7	102,000	5.4	95,000
CONNECTICUT	CHICOPEE	69.9	267,000	61.8	159,000	8.1	108,000	66.5	228,000	59.3	132,000	7.2	96,000
CONNECTICUT	SPRINGFIELD	29.6	281,000	21.8	175,500	7.8	105,500	25.8	235,400	19.4	146,000	6.4	89,400
CONNECTICUT	THOMPSONVILLE	16.6	282,000	11.4	177,000	5.2	105,000	14.4	236,000	10.0	148,000	4.4	87,400
CONNECTICUT	HARTFORD	37.8	291,000	30.1‡	188,000	7.5	102,000	35.4	251,000	28.1‡	166,000	7.3	85,000

* STATION SUBMERGED IN RESERVOIR. REDUCTION REFERS TO CHANNEL BELOW DAM.

\# AFFECTED BY BACKWATER.

** STAGES VARIABLE DUE TO ROLLER GATE OPERATION.

DENOTES FLOW BELOW MOUTH OF ASHUELOT RIVER.

‡ STAGES WITH AUTHORIZED HARTFORD AND EAST HARTFORD LEVEES COMPLETED.

TABLE XII EFFECT OF REVISED COMPREHENSIVE PLAN OF RESERVOIRS UPON THE DESIGN AND DEMONSTRATION FLOODS.

RIVER	STATION	DESIGN FLOOD						DEMONSTRATION FLOOD					
		COMPUTED		MODIFIED		REDUCTION		COMPUTED		MODIFIED		REDUCTION	
		STAGE FEET	DISCHARGE C.F.S.	STAGE FEET	DISCHARGE C.F.S.	STAGE FEET	DISCHARGE C.F.S.	STAGE FEET	DISCHARGE C.F.S.	STAGE FEET	DISCHARGE C.F.S.	STAGE FEET	DISCHARGE C.F.S.
PASSUMPSIC	PASSUMPSIC	26.1	20,700	20.5	15,300	5.6	5,400	40.4	34,800	31.2	25,700	9.2	9,100
AMMONOOSUC	BATH	12.7	19,000	8.4	7,120	4.3	11,880	16.5	32,000	10.4	12,000	6.1	20,000
WAITS	MOUTH	—	11,300	—	8,160	—	3,140	—	14,200	—	10,260	—	3,940
OMPOMPANOOSUC	MOUTH	—	10,200	—	1,870	—	8,330	—	12,800	—	5,180	—	7,620
WHITE	W. HARTFORD	18.3	41,900	13.8	21,500	4.5	20,400	20.5	55,000	15.7	29,100	4.8	25,900
MASCOMA	MASCOMA	9.1	10,000	7.5	5,750	1.6	4,250	9.2	10,100	7.6	5,800	1.6	4,300
OTTAUQUECHEE	W. HARTLAND*	15.8	20,000	—	3,480	—	16,520	15.4	19,000	—	2,640	—	16,360
SUGAR	W. CLAREMONT	13.5	20,700	6.5	5,200	7.0	15,500	13.6	20,900	6.1	4,800	7.5	16,300
BLACK	N. SPRINGFIELD	16.3	13,400	6.8	2,920	9.5	11,000	15.6	12,400	6.3	1,850	9.3	10,550
SAXTONS	MOUTH	—	8,430	—	2,870	—	5,560	—	7,450	—	2,140	—	5,360
WEST	NEWFANE*	16.1	26,900	—	—	—	31,740	15.4	24,700	—	—	—	32,090
ASHUELOT	WINSCALE	— #	29,600	13.1	20,300	—	9,300	— #	25,800	10.9	15,450	—	9,550
MILLERS	ERVING	12.3	25,200	9.9	15,500	2.4	9,700	11.4	21,500	8.9	11,940	2.5	9,560
CHICOPEE	BIRCHAM BEND	—	41,000	—	34,000	—	7,000	—	36,200	—	29,600	—	6,600
WESTFIELD	WESTFIELD	29.0	53,900	26.6	45,900	2.4	8,000	28.2	44,800	23.7	37,000	2.5	7,800
CONNECTICUT	S. NEWBURY	33.3	58,800	25.9	37,600	7.4	21,200	48.0	122,000	36.8	72,800	11.2	50,200
CONNECTICUT	WHITE RIVER JCT.	30.5	135,000	22.7	81,000	7.8	54,000	43,400	171,000	31.5	108,000	9.0	63,000
CONNECTICUT	BELLOWS FALLS**	304.7	190,500	292.2	94,500	12.5	96,000	311.5	240,000	297.4	132,500	14.1	113,500
CONNECTICUT	VERNON (H.W.)	139.9	237,500	131.7	115,000	8.2	122,500	142.5	278,000	133.0	143,000	9.5	135,000
CONNECTICUT	VERNON (T.W.)##	—	265,500	—	138,500	—	126,000	—	305,000	—	155,500	—	149,500
CONNECTICUT	MONTAGUE CITY	56.5	338,000	43.4	194,000	13.1	144,000	58.0	355,000	43.6	196,000	14.4	159,000
CONNECTICUT	NORTHAMPTON	136.8	341,500	126.3	186,500	1.5	155,000	137.8	357,000	126.6	202,000	11.2	155,000
CONNECTICUT	HOLYOKE	22.1	356,000	15.8	213,000	6.3	143,000	22.8	368,000	15.9	213,000	6.9	155,000
CONNECTICUT	CHICOPEE	73.5	405,000	68.5	243,000	5.0	162,000	78.4	412,000	67.4	235,000	11.0	177,000
CONNECTICUT	SPRINGFIELD	36.0	417,500	27.4	263,000	8.6	154,500	35.9	415,000	26.4	247,500	9.5	167,500
CONNECTICUT	THOMPSONVILLE	22.4	422,000	16.0	268,000	6.4	154,000	22.2	417,000	15.1	250,000	7.1	167,000
CONNECTICUT	HARTFORD	43.0‡	420,000	37.6‡	279,000	5.4	141,000	48.0‡	424,000	36.7‡	267,500	11.3	156,500

* STATION SUBMERGED IN RESERVOIR. REDUCTION REFERS TO CHANNEL BELOW DAM.

\# AFFECTED BY BACKWATER.

** STAGES VARIABLE DUE TO ROLLER GATE OPERATION.

DENOTES FLOW BELOW MOUTH OF ASHUELOT RIVER.

‡ STAGES WITH AUTHORIZED HARTFORD AND EAST HARTFORD LEVEES COMPLETED.

43. COSTS. - Estimates are prepared on the basis that the United States will bear costs of reservoirs including construction, lands, easements, utility relocations, and maintenance. In estimating the costs of dams and reservoirs the unit prices used have been based upon actual costs for similar work in the same general region. A summary of the total and annual costs of dams and reservoirs of the Revised Comprehensive Plan for flood control is shown in Table XIII. The detailed costs are given in Section 5 of the Appendix.

(Table XIII on following page)

TABLE XIII

SUMMARY OF RESERVOIR COSTS FOR FLOOD CONTROL ALONE

Reservoir	River	Construction	Railroads and utilities	Lands and damages	Highways	Total	Total annual
Massachusetts							
Knightville	Westfield	$ 1,752,000	$ 0	$ 91,000	$ 475,000	$ 2,318,000	$ 124,900
Easthampton	Manhan	753,000	53,000	185,000	240,000	1,231,000	68,800
Fort Morrison	Deerfield (North)	1,890,000	3,000	130,000	207,000	2,230,000	120,700
West Brookfield	Chicopee (Quaboag)	635,000	848,000	554,000	280,000	2,317,000	123,600
Barre Falls	Chicopee (Ware)	876,000	0	37,000	52,000	965,000	53,000
Tully	Millers (Tully)	502,000	31,000	45,000	87,000	665,000	39,200
Birch Hill	Millers	900,000	959,000	706,000	440,000	3,005,000	162,800
Lower Naukeag	Millers	416,000	1,000	94,000	37,000	548,000	34,400
New Hampshire							
Honey Hill	Ashuelot(South Branch)	1,398,000	5,000	242,000	290,000	1,935,000	107,900
Otter Brook	Ashuelot (Otter Brook)	1,279,000	3,000	43,000	182,000	1,507,000	79,100
Surry Mountain	Ashuelot	1,295,000	38,000	190,000	97,000	1,620,000	92,000
Claremont	Sugar	3,170,000	1,138,000	440,000	412,000	5,160,000	265,100
West Canaan	Mascoma	968,000	930,000	82,000	260,000	2,240,000	114,600
Sugar Hill	Ammonoosuc	3,500,000	1,696,000	570,000	764,000	6,530,000	327,900
Upper 15 Mile Falls	Connecticut	11,250,000	645,000	1,226,000	1,229,000	14,350,000	742,000
Vermont							
Williamsville	West	4,575,000	13,000	450,000	922,000	5,960,000	308,600
Cambridgeport	Saxtons	1,355,000	5,000	180,000	435,000	1,975,000	104,000
Brockway	Williams	1,380,000	1,066,000	160,000	338,000	2,944,000	150,300
North Springfield	Black	1,693,000	1,000	175,000	149,000	2,018,000	116,900
Ludlow	Black	925,000	28,000	314,000	474,000	1,741,000	97,100
North Hartland	Ottauquechee	3,300,000	1,000	300,000	29,000	3,630,000	191,100
South Tunbridge	White (First Branch)	1,305,000	7,000	460,000	503,000	2,275,000	128,300
South Randolph	White (Second Branch)	1,010,000	3,000	130,000	527,000	1,670,000	88,100
Ayers Brook	White (Ayers Brook)	645,000	3,000	83,000	179,000	910,000	51,500
Gaysville	White	2,130,000	16,000	420,000	1,514,000	4,080,000	224,900
Union Village	Ompompanoosuc	1,726,000	2,000	84,000	132,000	1,944,000	106,100
South Branch	Waits (South Branch)	1,040,000	0	55,000	175,000	1,270,000	70,600
Victory	Passumpsic (Moose)	729,000	0	81,000	213,000	1,023,000	60,100
Lyndonville	Passumpsic	1,850,000	5,000	190,000	185,000	2,230,000	119,300
TOTAL		$54,247,000	$7,500,000	$7,717,000	$10,827,000	$80,291,000	$4,272,900

44. BENEFITS. - The total average annual benefits for flood control which can be realized by the reservoirs of the Revised Comprehensive Plan are $4,715,400 of which $1,227,300 are annual direct benefits, $1,073,600 are annual indirect benefits, and $2,414,500 are annual restoration benefits. A summary of these benefits by zones are shown on Table XIV. The detailed computations of benefits are given in Section 2 of the Appendix.

(Table XIV on following page)

TABLE XIV

AVERAGE ANNUAL BENEFITS BY DAMAGE ZONES
FOR THE RESERVOIRS OF THE REVISED COMPREHENSIVE PLAN

Zone No.	Average Annual Benefits			
	Direct	Indirect	Restoration of property value	Total
		Main River		
C-1	$ 30,600	$ 19,900	$ 100	$ 50,600
C-2	26,600	23,100	0	49,700
C-3	40,000	39,100	1,400	80,500
C-4	32,700	29,200	200	62,100
C-5	37,800	35,300	5,000	78,100
C-6	23,900	15,800	100	39,800
C-7	214,300	182,100	205,000	601,400
C-8	246,200	211,200	906,000	1,363,400
C-9	15,200	14,700	10,200	40,100
C-10	266,900	247,400	1,240,000	1,754,300
Total main stem	934,200	817,800	2,368,000	4,120,000
		Tributaries		
1-a	5,200	4,800	0	10,000
1-b	5,700	5,200	500	11,400
1-c	5,800	5,800	100	11,700
1-d	3,500	3,100	0	6,600
4-b	9,000	7,500	100	16,600
5-a	300	200	0	500
7-a	5,500	4,200	100	9,800
7-b	600	500	0	1,100
7-c	1,400	1,300	0	2,700
7-d	2,400	2,100	0	4,500
7-e	5,700	6,500	0	12,200
8-a	1,400	1,400	100	2,900
8-b	11,700	7,200	300	19,200
10-b	4,500	3,900	0	8,400
11-a	31,800	22,800	1,200	55,800
11-b	1,000	700	100	1,800
11-c	14,500	13,900	2,000	30,400
12-a	1,200	1,100	0	2,300
13-a	900	800	0	1,700
14-a	300	200	900	1,400
14-b	15,700	13,100	9,000	37,800
14-c	26,200	20,500	0	46,700
14-f	6,200	6,900	0	13,100
14-n	400	300	200	900
15-c	5,400	5,200	500	11,100
15-e	5,700	6,400	3,800	15,900
15-g'	26,100	21,700	16,800	64,600
15-h'	25,300	26,000	2,700	54,000
15-f	100	100	0	200

(Continued next page)

TABLE XIV (Cont'd.)

Zone No.	Average Annual Benefits			
	Direct	Indirect	Restoration of property value	Total
	Tributaries (Continued)			
16-v	$ 2,200	$ 1,500	$ 0	$ 3,700
16-x	5,600	3,700	0	9,300
17-b	6,100	5,700	3,000	14,800
21-a	3,600	2,400	100	6,100
21-b	9,300	8,900	0	18,200
22-a	100	100	0	200
22-b	17,700	16,800	500	35,000
18-a	1,900	1,600	0	3,500
18-b	20,900	20,100	4,500	45,500
18-c	2,200	1,600	0	3,800
Total main stem	293,100	255,800	46,500	595,400
Total tributary	934,200	817,800	2,368,000	4,120,000
Grand total	1,227,300	1,073,600	2,414,500	4,715,400

45. DESCRIPTION OF RESERVOIRS. - Brief descriptions of the several reservoirs included in the Revised Comprehensive Plan follow. More detailed descriptions are given in Section 5 of the Appendix.

a. Knightville. - The Knightville dam site is located in Massachusetts on the Westfield River 27.8 miles above its confluence with the Connecticut River and in the village of Knightville. The dam will be of earth constructed by the hydraulic-fill method. The spillway is located in a natural saddle adjacent to the right abutment. The crest of the spillway will be 600.0 feet above mean sea level and 30 feet below the top of the dam. The reservoir outlet will consist of a gate-controlled tunnel in rock in the right abutment. The flood control capacity of the reservoir will be 39,300 acre-feet, equivalent to 4.5 inches of run-off from the drainage area of 164 square miles. With the reservoir filled to spillway crest, an area of 850 acres will be inundated, including a portion of Knightville. State Highway No. 112, a 24-foot bituminous macadam road, traverses the reservoir area and 3.5 miles of relocation will be necessary. In order to provide for possible future power storage in accordance with the recommendation of the Federal Power Commission for additional capacity, the height of the embankment will be 10 feet greater than is necessary for flood control storage, so that when the power potentialities at this site are developed, the spillway crest can be raised to elevation 610.0 feet above mean sea level. This will make available 13,700 acre-feet of power storage, equivalent to 1.6 inches of run-off, and will flood an additional area of 100 acres when the reservoir is filled to spillway crest. The maximum power pool will then be at 560.0 feet above mean sea level and will flood an area of 450 acres. In accordance with these provisions, the design of the structure has taken into account the possible raising of the spillway crest and the consequent additional load. The intake and a short section of the penstock will be constructed. The total cost of the dam and reservoir under these conditions of adaptability is estimated at $2,751,000, with total annual charges of $146,100. Of these values, $2,318,000 of the total

cost and $124,900 of the annual charges represent the amounts chargeable to flood control based on estimates of a single-purpose flood control reservoir. The reservoir will provide a high degree of flood protection to downstream communities on the Westfield River and will have a considerable flood-reducing effect on the Connecticut River at and below Springfield.

b. Easthampton. - The Easthampton dam site is located in Massachusetts on the Manhan River, 3.0 miles above its confluence with the Oxbow, an arm of the Connecticut River, in Easthampton. The dam will be of earth and will be constructed by rolled-fill methods. The spillway will be provided with a concrete gravity weir constructed on rock in the right abutment. The crest of the spillway weir will be 167.0 feet above mean sea level and 15 feet below the top of the dam. The outlet of the reservoir will consist of three gate-controlled reinforced-concrete conduits, constructed on rock in the right abutment, which will discharge into an open cut channel. The flood control capacity of the reservoir will be 21,800 acre-feet, which is equivalent to six inches of run-off from the drainage area of 68 square miles. With the reservoir filled to spillway crest, an area of 1,210 acres will be inundated. Several roads in the vicinity of the reservoir area, including State Highway No. 10, will require relocation or raising. This will include 1,500 feet of 24-foot bituminous macadam highway to be relocated, 900 feet of 16-foot gravel road to be raised along its present alignment, as well as 250 feet of 16-foot, 2,200 feet of 18-foot, and 1,300 feet of 20-foot bituminous macadam highways. These latter roads will be raised from 5 to 22 feet. A single-track line of the New York, New Haven and Hartford Railroad will be raised along its present alinement for 1,000 feet. The total cost of the dam and reservoir will be $1,231,000 with total annual charges of $68,800. The reservoir will have a considerable flood-reducing effect on the Connecticut River below the Oxbow at Northampton.

c. Fort Morrison. - The Fort Morrison dam site is located in Massachusetts on the East Branch of the North River, 6.6 miles above its confluence with the Deerfield River, and 1.2 miles north of Colrain. The dam will be of earth constructed by rolled-fill methods. A side-channel spillway will be located on rock in the right abutment. The crest of the spillway weir will be 711.0 feet above mean sea level and 17 feet below the top of the dam. The outlet of the reservoir will be provided by a gate-controlled concrete-lined tunnel excavated through rock in the left abutment. The flood control capacity of the reservoir will be 15,400 acre-feet, which is equivalent to 6.0 inches of run-off from the drainage area of 48 square miles. With the reservoir filled to spillway crest, an area of 400 acres, including Elm Grove, will be inundated. State Highway No. 112, an 18-foot bituminous macadam road, will require 2.7 miles of relocation. A 14-foot gravel road will be relocated for 0.6 mile. The total cost of the dam and reservoir is estimated at $2,230,000, with total annual charges of $120,700. The reservoir will provide a high degree of flood protection to the downstream communities of the Deerfield River, including Shelburne Falls, and will have a considerable flood-reducing effect on the Connecticut River below the mouth of the Deerfield River.

d. West Brookfield. - The West Brookfield dam site is located in West Brookfield in Massachusetts on the Quaboag River, 18.6 miles above its confluence with the Chicopee River. The dam will be of earth constructed by rolled-fill methods. A concrete gravity spillway section with a concrete apron will be constructed across the stream bed and on the left bank. The crest of the spillway will be 611.5 feet above mean sea level and 14.5 feet below the top of the dam. Four gate-controlled concrete conduits, located in the base of the spillway section, will serve as the outlet of the reservoir. The flood control capacity of the

reservoir will be 33,900 acre-feet, which is equivalent to 6.0 inches of run-off from the drainage area of 106 square miles. With the reservoir filled to spillway crest, an area of 4,000 acres will be flooded. The Village of West Brookfield will be protected from flooding by the reservoir. State Highway No. 9, a 20-foot concrete road, will require raising at three points for a total length of 1.0 mile. Relocation of 1.0 mile of an 18-foot bituminous macadam highway will be required by 0.7 mile of flooding. A 16-foot bituminous macadam road will require 1.0 mile of reconstruction. Relocation of 5.0 miles of a double-track line of the Boston and Albany Railroad will be required. The total cost of the dam and reservoir is estimated at $2,317,000, with total annual charges of $123,600. The reservoir will provide a high degree of flood protection to the downstream communities on the Quaboag River, including West Brookfield, Warren, West Warren, Palmer, and Three Rivers, and will have a considerable flood-reducing effect on the downstream reaches of the Chicopee and Connecticut Rivers.

c. Barre Falls. - The Barre Falls dam site is located in Barre Falls, Massachusetts, on the Ware River, 31.0 miles above its confluence with the Swift River. The dam will consist of an embankment of combined rolled-fill earth and rock-fill construction. Three auxiliary dikes will be of rolled-fill construction. A side-channel spillway will be excavated in rock in the right bank and will be provided with a broad-crested overflow weir. The crest of the spillway weir will be at elevation 815.5 feet on the Metropolitan District Water Supply Commission datum and 17 feet below the elevation of the top of the dam and dikes. A gate-controlled reinforced-concrete conduit, constructed on rock in the right abutment, will provide the outlet of the reservoir. The flood control capacity of the reservoir will be 24,300 acre-feet, which is equivalent to 8.0 inches of run-off from the

drainage area of 57 square miles. With the reservoir filled to spillway crest, an area of 1,450 acres will be inundated. State Highway No. 62, a 14-foot gravel road, will be flooded at various points and will probably be abandoned. Another 14-foot gravel road will require 1.0 mile of relocation. An access road, one mile in length, of the 14-foot gravel type will be constructed. The total cost of the dam and reservoir is estimated at $963,000, with total annual charges of $39,000. The reservoir will provide a high degree of flood protection for the downstream communities on the Ware River, including Ware, Thorndike, and Three Rivers, and will have an appreciable flood-reducing effect on the Chicopee River below Three Rivers, and on the Connecticut River below the mouth of the Chicopee River. A desire has been expressed by the State of Massachusetts for 8,000 acre-feet of conservation storage at this site. If this storage should be provided, at the expense of local interests, a siphon would be constructed to maintain the conservation pool at an elevation of 802.0 feet on the Metropolitan District Water Supply Commission datum, flooding an area of 850 acres. It would then be necessary to raise the top of the dam to 839.0 feet above mean sea level, and the spillway crest to 821.0 feet above mean sea level, in order to obtain the required flood control capacity. No other changes in the design of the dam and appurtenances would be required. An area of 1,850 acres would then be flooded when the reservoir was filled to spillway crest. The estimated cost of providing this conservation storage, over and above the cost for flood control, is $137,000, on which the annual charges are estimated at $8,100.

f. Tully. - The Tully dam site is located in Massachusetts on the Tully River 3.9 miles above its confluence with the Millers River and 1.0 mile above Fryeville. The dam will consist of an earth embankment of rolled-fill construction. The spillway will be located in a natural saddle southeast of the left abutment. Crest of the spillway will be 668.0 feet

above mean sea level and 17 feet below the top of the dam. The reservoir outlet will consist of a gate-controlled concrete-lined tunnel cut through rock in the left abutment. Flood control capacity of the reservoir will be 22,150 acre-feet, which is equivalent to 8.3 inches of run-off from the drainage area of 50 square miles. With the reservoir filled to spillway crest, an area of 1,100 acres will be inundated. Relocation of 1.0 mile of an 18-foot bituminous macadam highway and 2.5 miles of a 16-foot gravel road will be required. Development of power at the site is feasible and may be undertaken when the market for such power has sufficiently expanded. The interest charges on the excess cost of a higher dam if built at this time, over the uncertain period until such power might be profitably used, would be an economic loss of magnitude. Construction of a multiple-purpose dam should therefore be deferred. The dam has been designed so that it will be susceptible of raising in the future. Provision has been made so that the structure will be safe if the top of the dam and the spillway crest are elevated 36.0 feet. This will make available 53,450 acre-feet of power storage and will inundate an additional area of 750 acres when the reservoir is filled to spillway crest. The maximum power pool will then be at 691.0 feet above mean sea level and will flood 1,600 acres. The plan of the spillway has been modified for future adaptation to include power penstocks. The total cost of the dam and reservoir, under these conditions of adaptability, is estimated at $759,000, with total annual charges of $43,400. Of these values, $665,000 of the total cost and $39,200 of the annual charges represent the amounts chargeable to flood control based on estimates of a single-purpose flood control reservoir. The reservoir will provide a high degree of flood protection for the downstream communities on the Millers River, including Athol, Orange, and Millers Falls, and will have a considerable flood-reducing effect on the Connecticut River below the mouth of the Millers River.

g. Birch Hill. - The Birch Hill dam site is located in Massachusetts on the Millers River, 27.3 miles above its junction with the Connecticut River, and 1.3 miles northeast of South Royalston. The dam will consist of an earth embankment constructed by rolled-fill methods. The main spillway will be constructed on rock in a natural saddle on the right bank, and small auxiliary concrete spillway weirs will be located in an adjacent saddle. The spillway crest will be 852.0 feet above mean sea level, while the top of the dam will be 12 feet above this elevation. The reservoir outlet will consist of a gate-controlled open-cut channel excavated in rock in the right abutment of the dam. The flood control capacity of the reservoir will be 49,900 acre-feet, which is equivalent to 5.3 inches of run-off from the gross drainage area of 175 square miles, or to 6.0 inches of run-off from the net drainage area below Lower Naukeag dam site of 155 square miles. With the reservoir filled to spillway crest, an area of 3,200 acres will be inundated, including a low-lying portion of Baldwinsville. The Fitchburg Division of the Boston and Maine Railroad crosses the reservoir area, and 3.2 miles of double-track line will have to be relocated. U. S. Highway No. 202, a 20-foot bituminous macadam road, will require 6.0 miles of relocation. It will also be necessary to improve 1.5 miles of a local 16-foot gravel road. The total cost of the dam and reservoir is estimated at $3,005,000, with annual charges of $162,800. The reservoir will provide a high degree of flood protection for Athol, Massachusetts, and the several downstream communities on the Millers River, and will have a considerable flood-reducing effect on the Connecticut River below Turners Falls.

h. Lower Naukeag. - The Lower Naukeag dam site is located in Massachusetts on the Millers River, 41.7 miles above its confluence with the Connecticut River, and 1.5 miles north of North Ashburnham station. The dam will consist of an earth embankment of rolled-fill construction,

as will, also, the two auxiliary dikes. The spillway will consist of a concrete gravity weir with a concrete apron constructed in the dam. The crest of the spillway will be 1,075.5 feet above mean sea level, and 10 feet below the top of the dam and dikes. The outlet of the reservoir will consist of two gate-controlled conduits located in the base at the right end of the spillway section. The flood control capacity of the reservoir will be 8,530 acre-feet, which is equivalent to 8.0 inches of run-off from the drainage area of 20 square miles. With the reservoir filled to spillway crest, an area of 1,000 acres will be inundated. One mile of a 14-foot gravel road will be relocated, and 0.2 mile of a 16-foot gravel road will be raised on its present alinement. The total cost of the dam and reservoir is estimated at $548,000, with total annual charges of $34,400. The reservoir will provide a high degree of flood protection for the downstream communities of the Millers River, including Winchendon, South Royalston, Athol, Orange, and Millers Falls, and will have a considerable flood-reducing effect on the Connecticut River below the mouth of the Millers River. A desire has been expressed by the State of Massachusetts for 4,000 acre-feet of conservation storage at this site. If this storage should be provided, at the expense of local interests, a siphon would be constructed to maintain the conservation pool at an elevation of 1,071.0 feet above mean sea level, flooding an area of 830 acres. It would then be necessary to raise the top of the dam to 1,089.0 feet above mean sea level, and the spillway crest to 1,079.0 feet above mean sea level, in order to obtain the required flood control storage. No other changes in the design of the dam and appurtenances would be required. An area of 1,160 acres would then be flooded when the reservoir was filled to spillway crest. The estimated cost of providing this conservation storage, over and above the cost for flood control, is $112,000, on which the annual charges are estimated at $5,000.

i. Honey Hill. - The Honey Hill dam site is located in New Hampshire on the South Branch of the Ashuelot River, 5.6 miles above its confluence with the Ashuelot River, and 1.0 mile west of East Swanzey. The dam will consist of an earth embankment of rolled-fill construction. The spillway will consist of a concrete weir and channel constructed in the right abutment. The crest of the spillway weir will be 520.0 feet above mean sea level and 15 feet below the top of the dam. The outlet of the reservoir will consist of a gate-controlled reinforced-concrete conduit located in the right abutment. The flood control capacity of the reservoir will be 26,200 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 70 square miles. With the reservoir filled to spillway crest, an area of 1,360 acres, including a portion of East Swanzey, will be inundated. A 16-foot bituminous macadam road will require relocation for 1.8 miles. Another 16-foot bituminous macadam road will be rectified by the relocation of 0.8 mile, and the raising of 1.9 miles, along its present alinement. Flooding of 1.4 miles of a 16-foot bituminous macadam road will necessitate the abandonment of this road and the improvement of 1.1 miles of an alternate route, which is also a 16-foot bituminous macadam highway. The total cost of the dam and reservoir is estimated at $1,935,000, with total annual charges of $107,900. The reservoir will provide a high degree of flood protection for the downstream communities of the Ashuelot River, including West Swanzey, Winchester, and Hinsdale, and will have a considerable flood-reducing effect on the Connecticut River below the mouth of the Ashuelot River.

j. Otter Brook. - The Otter Brook dam site is located in New Hampshire, on Otter Brook, 4.9 miles above its confluence with the Ashuelot River, and 2.5 miles north of South Keene. The dam will consist of an earth embankment of rolled-fill construction. The spillway will consist of a channel excavated in the right abutment and provided with a

concrete overflow weir. The crest of the spillway weir will be 771.5 feet above mean sea level, and 15 feet lower than the top of the dam. The reservoir outlet will be provided by a gate-controlled reinforced-concrete conduit constructed in the right bank. The flood control capacity of the reservoir will be 17,500 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 47 square miles. With the reservoir filled to spillway crest, an area of 350 acres will be inundated. A 20-foot bituminous macadam road will require 1.6 miles of relocation. One and one-half miles of relocation will be likewise required for 1.3 miles of a 16-foot gravel road. The total cost of the dam and reservoir is estimated at $1,507,000, with total annual charges of $79,100. The reservoir will provide a high degree of flood protection for the downstream communities of Otter Brook and the Ashuelot River, including South Keene, West Swanzey, Winchester, and Hinsdale, will materially lessen flood stages at Keene by reduction of backwater effect, and will have an appreciable flood-reducing effect on the Connecticut River below its confluence with the Ashuelot River.

k. Surry Mountain. - The Surry Mountain dam site is located in New Hampshire on the Ashuelot River, 34.6 miles above its confluence with the Connecticut River and approximately 5 miles northwest of Keene. The dam will consist of an earth embankment of rolled-fill construction. A side channel spillway will be excavated in the right abutment, with its crest 550.0 feet above mean sea level and 15 feet below the top of the dam. The reservoir will be provided with an outlet consisting of a gate-controlled tunnel excavated in rock in the right abutment. The flood control capacity of the reservoir will be 32,500 acre-feet, which is equivalent to 6.1 inches of run-off from the tributary drainage area of 100 square miles. With the reservoir filled to spillway crest, an area of 970 acres will be flooded, including a section of Surry. An 18-foot

bituminous macadam road will be relocated for a length of 3.1 miles. The total cost of the dam and reservoir is estimated at $1,620,000, with annual charges of $92,000. The reservoir will provide a major degree of flood protection for Keene, New Hampshire, and other localities on the Ashuelot River, and will have a considerable flood-reducing effect on the Connecticut River below its confluence with the Ashuelot River.

1. Claremont. - The Claremont dam site is located in New Hampshire on the Sugar River, 7.1 miles above its confluence with the Connecticut River, and one mile southeast of Claremont. The dam will consist of an earth embankment of rolled-fill construction. A side-channel spillway will be constructed on rock in the left abutment. The crest of the spillway weir will be 627.5 feet above mean sea level, and 15 feet below the top of the dam. The reservoir outlet will consist of a gate-controlled concrete conduit constructed in rock in the left abutment. The flood control capacity of the reservoir will be 78,400 acre-feet, which is equivalent to 6.0 inches of run-off from the drainage area of 245 square miles. With the reservoir filled to spillway crest, an area of 1,500 acres, including Puckershire, will be flooded. State Highways Nos. 11 and 103, 18-foot concrete roads, will require 2.1 miles of relocation. Two miles of relocation will also be required for each of two 18-foot bituminous macadam highways. A 16-foot gravel road will require 2.0 miles of relocation. Two and one-half miles of a single-track branch of the Boston and Maine Railroad lie within the reservoir area, requiring 4.0 miles of relocation. The total cost of the dam and reservoir is estimated at $5,160,000 with total annual charges of $265,100. The reservoir will provide a major degree of flood protection for Claremont and West Claremont on the Sugar River, and will have a considerable flood-reducing effect on the Connecticut River below its confluence with the Sugar River.

m. West Canaan. - The West Canaan dam site is located in New Hampshire on the Mascoma River 19.5 miles above its confluence with the Connecticut River, and 1.5 miles east of West Canaan. The dam will consist of an earth embankment of rolled-fill construction. The spillway will consist of a broad-crested concrete weir at the right end of the embankment. The crest of the spillway will be 910.0 feet above mean sea level and 17.0 feet below the top of the dam. The outlet of the reservoir will be provided with a gate-controlled reinforced-concrete conduit located in the left abutment. The storage capacity of the reservoir will be 53,500 acre-feet, which is equivalent to 12.5 inches of run-off from the drainage area of 80 square miles. Of this storage 34,100 acre-feet, equal to 8.0 inches of run-off, are to be utilized for flood control. The remainder will be devoted to conservation. The conservation pool will be maintained by means of a siphon at 8[illegible].0 feet above mean sea level, flooding an area of 1220 acres. With the reservoir filled to spillway crest, an area of 1900 acres will be inundated. Relocation of 4.0 miles of a 20-foot bituminous macadam highway will be required. It will also be necessary to relocate 6.0 miles of single track main line of the Boston & Maine Railroad. The total cost of the dam and reservoir is estimated at $2,520,000, with total annual charges of $128,400. Of these values, $2,240,000 of the total cost of $114,600 of the annual cost, represent the amounts chargeable to flood control based on estimates of a single-purpose flood control reservoir. The reservoir will provide a high degree of flood protection for the downstream communities on the Mascoma River, including Enfield and Lebanon, and will have an appreciable flood-reducing effect on the Connecticut River below the mouth of the Mascoma River.

n. Sugar Hill. - The Sugar Hill dam site is located in New Hampshire on the Ammonoosuc River, 14.7 miles above its confluence with the Connecticut River, and 2.8 miles northeast of Lisbon. The dam will consist of

an earth embankment of rolled-fill construction. A concrete gravity overflow weir will be built on rock in the right abutment. The spillway crest will be 739.0 feet above mean sea level and 20 feet below the top of the dam. The outlet of the dam will consist of a gate-controlled concrete-lined tunnel constructed in rock in the right abutment. The flood control capacity of the reservoir will be 91,600 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 246 square miles. With the reservoir filled to spillway crest, an area of 1750 acres, including Barrett, will be inundated. U. S. Highway No. 302, an 18-foot concrete road, will require 7.5 miles of relocation. Relocation of 2.4 miles of 16-foot gravel road will also be required. The White Mountain Division of the Boston and Maine Railroad, a single-track line, will require 9.0 miles of relocation. The total cost of the dam and reservoir is estimated at $6,530,000, with total annual charges of $327,900. The reservoir will provide a high degree of flood protection for the downstream communities on the Ammonoosuc River, including Lisbon and Bath, and will have a considerable flood-reducing effect on the Connecticut River below Woodsville.

o. Upper Fifteen Mile Falls. - The Upper Fifteen Mile Falls dam site is located on the main stem of the Connecticut River 238 miles above the mouth and 1.0 mile southwest of Waterford, Vermont, and 0.5 mile west of Pattenville, New Hampshire. The dam will be an embankment of combined rolled-fill earth and rock-fill. A concrete-lined spillway will be excavated in rock in the left abutment. The crest of the spillway will be 851.0 feet above mean sea level and 25 feet below the top of the dam. The outlet of the reservoir will be provided by 2 gate-controlled tunnels cut through rock in the left abutment. The flood control capacity of the reservoir will be 476,000 acre-feet, which is equivalent to 5.5 inches of run-off from the drainage area of 1626 square miles. With the reservoir filled to spillway crest, an area of 12,800 acres will be inundated, including

Waterford, Vermont, North Littleton and Pattenville, New Hampshire, and portions of Gilman, South Lunenburg, Guildhall Station, and Guildhall in Vermont, and Cushman, Lancaster, Northumberland, and Groveton in New Hampshire. U. S. Route No. 2, a 20-foot bituminous macadam highway, will require raising of the road for 1.0 mile. New Hampshire State Highway No. 18, a 20-foot bituminous macadam road, will require 5.6 miles of relocation. 2.4 miles of relocation and 1.0 mile of improvement of a 20-foot bituminous macadam road will be necessitated for a distance of 3.2 miles. Relocation of 5.4 miles of 18-foot gravel road and 2.1 miles of 16-foot gravel road will be required. A single track line of the Maine Central Railroad will lie within the reservoir area for a length of 3.0 miles, necessitating 3.2 miles of relocation. Development of power at this site is feasible and may be undertaken when the market for such power has sufficiently expanded. A market for this power is not now assured. If and when the power potentialities at this site are developed, 216,000 acre-feet of storage, equivalent to 2.5 inches of run-off, will be utilized for this purpose. The remainder will be retained for flood control. Under these conditions the elevation of the maximum power pool will be 806.0 feet above mean sea level, and it will flood 3500 acres. The present plan of construction includes adaptations for possible future power plant installation. The total cost of the dam and reservoir under these conditions of adaptability is estimated at $14,835,000, with total annual charges of $764,000. Of these values, $14,350,000 of the total cost of $742,000 of the annual charges represent the amounts chargeable to flood control, based on estimates of a single purpose flood control reservoir. The reservoir will have a considerable flood-reducing effect on the downstream reaches of the Connecticut River.

p. Williamsville. - The Williamsville dam site is located in Vermont on the West River, 8.3 miles above its confluence with the Connec-

ticut River, and 2.0 miles east of Williamsville. The dam will consist of an earth embankment of rolled-fill construction. A concrete side-channel spillway will be built on rock in the right abutment. The crest of the spillway will be 473.0 feet above mean sea level and 21.0 feet below the top of the dam. The outlet of the reservoir will consist of a gate-controlled concrete-lined tunnel cut through rock in the right abutment. The flood control capacity of the reservoir will be 150,000 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 400 square miles. With the reservoir filled to spillway crest, an area of 2300 acres will be inundated, including Harmonyville. State Highway No. 30 will be flooded, necessitating 8.1 miles of relocation of 18-foot bituminous macadam road and 3.8 miles of 18-foot gravel road. A 16-foot gravel road will require 4.5 miles of relocation. Development of power at this site is feasible and may be undertaken when the market for such power has sufficiently expanded. The interest charges on the excess cost of a higher dam if built at this time, over the uncertain period until such power might be profitably used, would be an economic loss of magnitude. Construction of multiple-purpose dam should therefore be deferred. The dam has been designed so that it will be susceptible of raising in the future. Provision has been made that the structure will be safe if the top of the dam and the spillway crest are elevated 30.0 feet, which will make available 103,000 acre-feet of power storage, and will inundate an additional area of 1020 acres when the reservoir is filled to spillway crest. The maximum power pool will be at 460.0 feet above mean sea level and will flood 2330 acres. Highway relocations have been planned so that no future changes in them will be necessary. The total cost of the dam and reservoir, under these conditions of adaptability, is estimated at $6,280,000, with total annual charges of $324,400. Of these values, $5,960,000 of the total cost

and $308,600 of the annual charges are the amounts chargeable to flood control, based on estimates of a single-purpose flood control reservoir. The reservoir will have a considerable flood-reducing effect on the Connecticut River below its confluence with the West River.

q. Cambridgeport. - The Cambridgeport dam site is located in Vermont on the Saxtons River, 7.8 miles above its confluence with the Connecticut River, and 0.6 mile southeast of Cambridgeport, and 2 miles northwest of Saxtons River. The dam will consist of an earth embankment of rolled-fill construction. A concrete side-channel spillway will be built on rock in the left abutment. The crest of the spillway weir will be 642.0 feet above mean sea level and 15 feet lower than the top of the dam. The outlet of the reservoir will consist of a gate-controlled concrete-lined tunnel located in rock in the left abutment. The flood control capacity of the reservoir will be 21,600 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 58 square miles. With the reservoir filled to spillway crest, an area of 650 acres will be inundated including Cambridgeport and a portion of Athens. State Highway No. 121, an 18-foot bituminous macadam road, will be relocated for a distance of 1.6 miles. An 18-foot gravel road will require 3.0 miles of relocation. A 14-foot gravel road will also require relocation for 0.5 mile. The total cost of the dam and reservoir is estimated at $1,775,000, with total annual charges of $104,000. The reservoir will provide a high degree of flood protection for the downstream communities on the Saxtons River, including Saxtons River, and will have a considerable flood reducing effect on the Connecticut River below Bellows Falls.

r. Brockway. - The Brockway dam site is located in Vermont on the Williams River, 5.5 miles above its confluence with the Connecticut River, and 0.4 mile west of Brockway Mills. The dam will consist of

an earth embankment of rolled-fill construction. The spillway will be provided with a concrete gravity weir built on rock in the left abutment. The crest of the spillway will be 552.5 feet above mean sea level and 15 feet below the top of the dam. The outlet of the reservoir will consist of a gate-controlled concrete-lined tunnel located in rock in the left abutment. The flood control capacity of the reservoir will be 32,300 acre-feet, which is equivalent to 6.0 inches of run-off from the drainage area of 101 square miles. With the reservoir filled to spillway crest, an area of 320 acres, including a portion of Bartonsville, will be inundated. State Highway No. 103, an 18-foot bituminous macadam road, will require 2.6 miles of relocation. Relocation of 3.6 miles of 16-foot gravel road will be required. A single-track line of the Rutland Railroad lies within the reservoir area for a distance of 4.0 miles, and 5.8 miles of relocation will thus be required. The total cost of the dam and reservoir is estimated at $2,944,000, with annual charges of $150,300. The reservoir will have a considerable flood-reducing effect on the Connecticut River below the mouth of the Williams River.

s. North Springfield. - The North Springfield dam site is located in Vermont on the Black River, 8.2 miles above its confluence with the Connecticut River, and 0.5 mile northeast of North Springfield. The dam will consist of an earth embankment of rolled-fill construction. A concrete gravity overflow spillway will be built on rock in the right abutment. The crest of the spillway will be 523.5 feet above mean sea level and 19 feet below the top of the dam. The outlet of the reservoir will consist of five gate-controlled conduits located in the base of the spillway section. The flood control capacity of the reservoir will be 33,400 acre-feet, which is equivalent to 6.2 inches of run-off from the net drainage area of 102 square miles below the Ludlow dam site. With the reservoir

filled to spillway crest, an area of 960 acres, including a portion of Perkinsville, will be flooded. State Highway No. 106, an 18-foot bituminous macadam road, will require 0.7 mile of relocation. A short length of a 16-foot gravel road will require relocation. The total cost of the dam and reservoir is estimated at $2,018,000, with total annual charges of $116,900. The reservoir will provide a high degree of flood protection to Springfield on the Black River, and will have an appreciable flood-reducing effect on the Connecticut River below the mouth of the Black River.

t. Ludlow. - The Ludlow dam site is located in Vermont on the Black River, 27.7 miles above its confluence with the Connecticut River, and 0.75 mile northwest of Ludlow. The dam will consist of an earth embankment of rolled-fill construction. A side-channel spillway will be constructed on rock in the right abutment. The crest of the spillway weir will be 1090.0 feet above mean sea level and 21 feet below the top of the dam. The outlet of the reservoir will consist of a gate-controlled reinforced-concrete conduit constructed in a rock cut in the right abutment. The storage capacity of the reservoir will be 54,000 acre-feet, which is equivalent to 18.0 inches of run-off from the drainage area of 56 square miles. Of this storage, 23,000 acre-feet, equal to 8.0 inches of run-off, are to be utilized for flood control. The remainder will be devoted to conservation. The conservation pool will be maintained, by means of a siphon, at 1074.0 feet above mean sea level, flooding an area of 1200 acres. With the reservoir filled to spillway crest, an area of 1600 acres, including Grahamville, will be inundated. A length of State Highway No. 103 will require 1.3 miles of relocation of 18-foot concrete road and 0.6 mile of relocation of 18-foot bituminous macadam road. State Highway No. 100, an 18-foot bituminous macadam road, will require 2.6 miles of relocation. It will also be necessary to improve 6.4 miles of a 16-foot gravel road. The total cost of the

dam and reservoir is estimated at $2,200,000, with total annual charges of $124,000. Of these values, $1,741,000 of the total cost and $97,100 of the total annual charges represent the amounts chargeable to flood control, based on estimates of a single-purpose flood control reservoir. The reservoir will provide a high degree of flood protection for the downstream communities on the Black River, including Ludlow, Perkinsville, North Springfield, and Springfield, and will have a considerable flood-reducing effect on the Connecticut River below the mouth of the Black River.

u. North Hartland. - The North Hartland dam site is located in Vermont on the Ottauquechee River, 1.5 miles above its confluence with the Connecticut River, and 1.0 mile northwest of North Hartland. The dam will consist of an earth embankment of rolled-fill construction, as will the auxiliary dike. A side-channel spillway will be excavated in rock in the left abutment. The crest of the spillway weir will be 546.5 feet above mean sea level and 17 feet below the top of the dam and dike. The outlet of the reservoir will consist of a gate-controlled concrete-lined tunnel cut through rock in the left abutment. The flood control capacity of the reservoir will be 71,100 acre-feet, which is equivalent to 6.0 inches of run-off from the drainage area of 222 square miles. With the reservoir filled to spillway crest, an area of 1120 acres will be flooded. An 18-foot gravel road will require 1.0 mile of relocation. The total cost of the dam and reservoir is estimated at $3,630,000, with total annual charges of $191,100. The reservoir will have a material flood-reducing effect on the Connecticut River below the mouth of the Ottauquechee River.

v. South Tunbridge. - The South Tunbridge dam site is located in Vermont, on the First Branch of the White River, one mile above its confluence with the White River and 1.5 miles north of South Royalton.

The dam will consist of an earth embankment of rolled-fill and rock construction, with a side-channel spillway built in rock in the left abutment. The crest of the spillway will be 564.0 feet above mean sea level and 21.0 feet below the top of the dam. The outlet of the reservoir will consist of a gate-controlled reinforced-concrete conduit constructed in the rock floor of the left bank. The flood control capacity of the reservoir will be 32,600 acre-feet, which is equivalent to 6.0 inches of run-off from the drainage area of 102 square miles. With the reservoir filled to spillway crest, an area of 860 acres will be inundated, including a portion of the village of South Tunbridge. State Highway No. 110 will require 4.0 miles of relocation of 18-foot bituminous macadam road. Two 14-foot gravel roads will require 2.6 miles of relocation. Relocation of 6.5 miles of telephone and electric distribution lines will also be necessary. The total cost of the dam and reservoir is estimated at $2,275,000, with total annual charges of $128,300. The reservoir would have a considerable flood-reducing effect on the White River and on the Connecticut River below White River Junction.

w. South Randolph. - The South Randolph dam site is located in Vermont on the Second Branch of the White River, 5.0 miles above its confluence with the White River, and 0.5 mile northeast of East Bethel. The dam will consist of an earth embankment of rolled-fill construction. The spillway will consist of a concrete broad-crested weir built on rock in the left abutment. The spillway crest will be 596.5 feet above mean sea level and 20 feet below the top of the dam. The outlet of the reservoir will consist of a gate-controlled concrete-lined tunnel cut through rock in the left abutment. The flood control capacity of the reservoir will be 23,500 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 63 square miles. With the reservoir filled to spillway crest, an area of 630 acres, including South Randolph and

a portion of East Randolph, will be inundated. State Highway No. 14, an 18-foot bituminous macadam road, will require 4.6 miles of relocation and 1.3 miles of improvement. The total cost of the dam and reservoir is estimated at $1,670,000, with total annual charges of $88,100. The reservoir will provide a high degree of flood protection for the downstream communities of the White River, including Royalton, South Royalton, West Hartford, and Hartford, and will have an appreciable flood-reducing effect on the Connecticut River below White River Junction.

x. Ayers Brook. - The Ayers Brook dam site is located in Vermont on Ayers Brook, 1.2 miles above its junction with the Third Branch of the White River, and one mile north of Randolph. The dam will consist of an earth embankment of rolled-fill construction. A concrete side-channel spillway will be constructed in the right abutment. The crest of the spillway weir will be 697.5 feet above mean sea level and the top of the dam will be 15 feet above this elevation. The reservoir outlet will consist of a gate-controlled reinforced-concrete conduit located in rock in the right abutment. The flood control capacity of the reservoir will be 11,200 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 30 square miles. With the reservoir filled to spillway crest, an area of 610 acres will be inundated. State Highway No. 12, an 18-foot bituminous macadam road, will require relocation for 3.0 miles. It will also be necessary to relocate a 16-foot gravel road for 0.5 mile. The total cost of the dam and reservoir is estimated at $910,000, with total annual charges of $51,500. The reservoir will provide a high degree of flood protection for the downstream damage centers on the White River and will have a considerable flood-reducing effect on the Connecticut River below White River Junction.

y. Gaysville. - The Gaysville dam site is located in Vermont on the White River, 31.6 miles above its confluence with the Connecticut River, and 0.5 mile southwest of Gaysville. The dam will be of concrete arch construction. The spillway will consist of a concrete gravity overflow section at the right end of the dam. The crest of the spillway will be 798.0 feet above mean sea level and 21.0 feet below the top of the dam. The reservoir outlet will consist of 4 gate-controlled conduits through the base of the arch dam. The flood control capacity of the reservoir will be 84,300 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 226 square miles. With the reservoir filled to spillway crest, an area of 1860 acres will be inundated, including portions of Stockbridge, Tupper, and Emerson. State Highway No. 107, an 18-foot bituminous macadam road, will require 7.2 miles of relocation. State Highway No. 100, an 18-foot gravel road, will require 7.0 miles of relocation. A 16-foot gravel road will require relocation for 0.6 mile. Development of power at this site is feasible and may be undertaken when the market for such power has sufficiently expanded. The interest charges on the excess cost of a higher dam if built at this time, over the uncertain period until such power might be profitably used, would be an economic loss of magnitude. Construction of a multiple-purpose dam should therefore be deferred. The dam has been designed so that it will be susceptible of raising in the future. Provision has been made so that the structure will be safe if the top of the dam and the spillway crest are elevated 19.0 feet. This will make available 40,000 acre-feet of power storage, and will inundate an additional area of 380 acres when the reservoir is filled to spillway crest. The maximum power pool will then be at 767.0 feet above mean sea level and will flood 1090 acres. Highway relocations have been planned so that no further changes in them will be necessary. The total cost of the dam and reservoir, under these condi-

ditions of adaptability, is estimated at $4,785,000, with total annual charges of $261,600. Of these values, $4,080,000 of the total cost and $224,900 of the annual charges represent the amounts chargeable to flood control, based on estimates of a single-purpose flood control reservoir. The reservoir will provide a high degree of flood protection for the downstream communities on the White River, including Gaysville, Bethel, Royalton, South Royalton, West Hartford, and Hartford, and will have an appreciable flood-reducing effect on the Connecticut River below the mouth of the White River.

z. Union Village. - Union Village dam site is located in Vermont on the Ompompanoosuc River, 4.1 miles above its junction with the Connecticut River, and 0.3 mile north of Union Village. The dam will consist of an earth embankment of hydraulic-fill construction. The spillway will be in ledge rock at the bottom of a deep earth cut in the right abutment, and will be provided with a concrete weir. The crest of the spillway will be 554.0 feet above mean sea level and 30 feet below the top of the dam. The reservoir outlet will consist of a gate-controlled tunnel in rock in the left abutment. A small recreation pool will be maintained at Elevation 460.0 by means of a siphon. The flood control capacity of the reservoir will be 30,200 acre-feet, which is equivalent to 4.5 inches of run-off from the drainage area of 126 square miles. With the reservoir filled to spillway crest, an area of 650 acres will be inundated. A 16-foot gravel road will require 1.2 miles of relocation and 1.8 miles of raising the road along its present alinement. In accordance with a recommendation of the Federal Power Commission for additional capacity, the height of the embankment will be 10 feet greater than is necessary for flood control storage, in order to provide for possible future power storage. If and when the power potentialities of this site are developed, the spillway crest will be raised to 564.0 feet above mean sea level. This will make available 7400 acre-feet of power storage and will flood an additional area of 70 acres when the reservoir is filled to spillway crest.

The maximum power pool will then be 502.0 feet above mean sea level and will inundate an area of 250 acres. In accordance with these provisions the design of the structure has taken into account the possible raising of the spillway crest and the consequent additional load, and the intake and take-off of a penstock will be constructed. The total cost of the dam and reservoir under these conditions of adaptability is estimated at $2,376,000, with total annual charges of $125,900. Of these values $1,944,000 of the total cost, and $106,100 of the annual charges, represent the amounts chargeable to flood control based on estimates of a single-purpose flood control reservoir. The reservoir will provide a major degree of flood protection to downstream communities on the Ompompanoosuc River and will have a substantial flood-reducing effect on the Connecticut River at and below Hanover.

aa. South Branch. - The South Branch dam site is located in Vermont, on the South Branch of the Waits River, 1-1/2 miles above its junction with the Waits River. The dam will consist of an earth embankment of rolled-fill construction. The spillway will be constructed of reinforced concrete 54 feet in diameter and will discharge into a 23-foot diameter reinforced-concrete conduit embedded in rock. The crest of the spillway will be 815.0 feet above mean sea level, 18.0 feet below the top of the dam. The outlet of the reservoir will consist of a gate-controlled reinforced-concrete conduit constructed on rock. The flood control capacity of the reservoir will be 16,800 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 45 square miles. With the reservoir filled to spillway crest, an area of 570 acres will be inundated. An 18-foot gravel road will require 3.9 miles of relocation. A 16-foot gravel road will require 1.2 miles of relocation. Conservation storage at this site may be feasible in the future, but will not be developed until the need for it is evidenced. Accordingly, the dam has been designed so

that it will be susceptible of raising in the future. Provisions have been made so that the structure will be safe if the top of the dam and the spillway crest are elevated 29.0 feet, which will provide 24,200 acre-feet of conservation storage. Highway relocations have been planned for the ultimate condition. If conservation storage is provided in the future the conservation pool level would be maintained by means of a siphon to be installed at that time, at 826.0 feet above mean sea level. The pool would flood an area of 700 acres. The same amount of flood control storage would be provided above the conservation pool and an area of 950 acres would be flooded at the spillway crest. The total cost of the dam and reservoir, under these conditions of adaptability, is estimated at $1,392,000 with total annual charges of $75,500. Of these values $1,270,000 of the total costs and $70,600 of the annual charges are the amounts chargeable to flood control, based on estimates of a single-purpose flood control reservoir. The reservoir would have a considerable flood-reducing effect on the Connecticut River below the mouth of the Waits River with minor tributary benefits.

bb. Victory. - The Victory dam site is located in Vermont on Moose River, 17.2 miles above its junction with the Passumpsic River, and 4 miles north of North Concord. The dam will consist of an earth embankment of rolled-fill construction. A concrete gravity section spillway will be provided in the right abutment. The spillway crest will be 1175.0 feet above mean sea level and 17 feet below the top of the dam. The outlet of the reservoir will consist of a gate-controlled concrete conduit located in the right abutment. The storage capacity of the reservoir will be 81,000 acre-feet, which is equivalent to 23.0 inches of run-off from the drainage area of 66 square miles. Of this storage, 28,200 acre-feet, equal to 8.0 inches of run-off, are to be utilized for flood control. The remainder will be devoted to conservation. The conservation pool will be

maintained by means of a siphon at 1164.0 feet above mean sea level, flooding an area of 2300 acres. With the reservoir filled to spillway crest, an area of 2830 acres will be inundated. Relocation of 4.6 miles of an 18-foot gravel road will be required. The total cost of the dam and reservoir is estimated at $1,415,000, with total annual charges of $80,200. Of these values, $1,023,000 of the total cost and $60,100 of the annual charges represent the amounts chargeable to flood control based on estimates of a single-purpose flood control reservoir. The reservoir will provide a high degree of flood protection to the downstream communities on the Passumpsic River, including St. Johnsbury, and will have an appreciable flood-reducing effect on the Connecticut River below the mouth of the Passumpsic River.

cc. Lyndonville. - The Lyndonville dam site is located in Vermont on the Passumpsic River, 24.0 miles above its confluence with the Connecticut River, and 2.0 miles northeast of Lyndonville. The dam will consist of an earth embankment of rolled-fill construction. A concrete overflow weir will be constructed on rock in the spillway channel which will be excavated in the right bank. The crest of the spillway weir will be 844.0 feet above mean sea level and 15 feet below the top of the dam. The outlet of the reservoir will consist of a reinforced-concrete conduit located on rock in the right abutment. The flood control capacity of the reservoir will be 26,100 acre-feet, which is equivalent to 7.0 inches of run-off from the drainage area of 70 square miles. With the reservoir filled to spillway crest, an area of 600 acres, including a portion of East Burke, will be inundated. State Highway No. 114, an 18-foot gravel road, will require relocation for 0.5 mile. Three miles of other existing roads will be improved on their present alinement. The total cost of the dam and reservoir is estimated at $2,230,000, with total annual charges of $119,300. The reservoir will provide a high degree of flood protection to the downstream communities of the Passumpsic River, including Lyndonville, Lyndon, and St. Johnsbury, and will have an appreciable flood-reducing effect on the Connecticut River below the mouth of the Passumpsic River.

46. PRACTICABILITY OF LEVEE PROTECTION. - Flood protection by means of levees is practicable, in general, only where large flood losses are concentrated in relatively short reaches along a stream. This condition is further emphasized when a system of reservoirs, justified by its widespread general protection, provides partial protection to reaches where losses are concentrated, and levees must be justified by the residual benefits only. In highly industrialized or thickly populated areas where losses are great, the complete protection furnished by levees is necessary in addition to the reduction of flood flows by storage reservoirs. In the Connecticut Valley, consequently, flood protection by means of levees is most adapted to the cities located along the main river in Connecticut and Massachusetts that fall in the above category. Significantly, these are the areas which have made concerted efforts in the past to protect themselves by levees. In Vermont and New Hampshire, and on the tributaries in Connecticut and Massachusetts, the flood losses are scattered over wider areas. The few more populous centers subject to heavy flood losses are located on the banks of streams in such a way that levee construction is usually impracticable, costing more than the value of the protection. Levee protection to rural areas is not ordinarily justified because of the relatively small and scattered benefits to be derived, and the extensive levees and pumping facilities which would be necessary. If continuous levee protection were provided along the Connecticut River to protect all places which suffered damage, the amount of natural valley storage which the flooded areas formerly afforded would be considerably decreased. The flood waters which formerly spread through this natural valley storage would then have to be carried in the restricted channel or flood-way between the levees and the resulting flood plane for a given run-off would be higher. The greater the extension of the levee system, the greater

the effect described above, and the higher the levee grades that would be required. The cost of a system of protection by levees alone would be prohibitive. A balanced system of reservoirs reducing the flood damage to negligible amounts in all but the most congested regions, and lowering the elevations required of levees at those points affords the most economical solution. The reservoirs retard flood flows and reduce flood stages in the lower river, and provide substantial benefits to the communities where levee protection cannot be justified. At those communities where local protection is justified, the levees provide complete protection against design flood stages reduced by the reservoir system. The levees in such a plan would of course provide protection against lesser floods, but only when supported by the reservoir system are they completely effective against major floods.

47. EXISTING LEVEES. - State, municipal, and private interests have provided local protection by means of levees at various points along the Connecticut River in Massachusetts and Connecticut. There are no existing levees in the Connecticut Valley in Vermont and New Hampshire. The height of existing levees varies with the locality. Prior to the flood of March 1936, most of these levees were constructed to an elevation to give protection against a flood of the magnitude of that which occurred in November 1927. The flood of March 1936 overtopped all levees in the Connecticut Valley. As a result of this overtopping some of the existing levees were raised to protect against flood stages equal to those of March 1936. At Holyoke and Chicopee, Massachusetts, this work was done by the respective municipalities. At Springfield and West Springfield, in Massachusetts, and at Hartford, Connecticut, this work was executed under the supervision of the Engineer Department as Work Relief projects, with the costs divided between local interests and the Federal Government in accordance with the provisions of the Flood Control Act approved June 22,

1936. At Hatfield and Hadley in Massachusetts, the existing levees were repaired after the flood of March 1936, also as Work Relief projects under the supervision of the Engineer Department. The flood of September 1938 overtopped levees at Northampton, Chicopee, and Agawam, and the levee at Hartford would have been overtopped and flanked, had it not been temporarily raised with sandbags at the time of the flood. The levee at Hatfield failed without being overtopped. In general, existing works provide for drainage behind the levees by means of intercepting sewers and pumping plants. In a few rural areas in Massachusetts, levees have been constructed to prevent destructive erosion of fertile farm lands, but do not provide protection from inundation of land at high stages of the river.

48. LEVEE GRADES. - The levee design grades are shown in Table XV. These grades were predicated on the stages of the design flood as proposed in the Comprehensive Report and reduced by the Comprehensive Plan of reservoirs. The discharges and stages of the revised design flood, and as modified by the 29 reservoirs of the Revised Comprehensive Plan, are also given in Table XV, and show the effect of the revisions on existing levee grades. It may be seen from the table that the stages of the revised design flood, unreduced, are from 7 to 9 feet higher than the top elevations of concrete wall. This difference graphically demonstrates the necessity of supplementing the levee protection with a large system of reservoirs.

(Table XV on following page)

TABLE XV - LEVEE GRADES

Site	Revised design flood				Authorized levee grades in feet		
	Stage in feet		Discharge in cubic feet per second		Design	Top of earth levee	Top of concrete wall
	Natural	Modified by 29 reservoirs	Natural	Modified by 29 reservoirs			
Hartford and East Hartford, Conn. (Memorial Bridge)	47.4	37.0	420,000	279,000	35.5	40.5	38.5
Springfield and West Springfield, Mass. (Memorial Bridge)	73.3	64.7	417,500	263,000	63.6	68.6	66.6
Chicopee, Massachusetts (Chicopee Bridge)	78.5	68.5	405,000	243,000	67.6	72.6	70.6
Holyoke, Massachusetts (Above County Bridge)	88.8	74.4	356,000	213,000	77.0	82.0	80.0
Northampton, Massachusetts	136.8	126.3	341,500	198,500	127.0	132.0	130.0

49. LEVEES UNDER CONSTRUCTION. - Levee projects at seven localities as recommended in House Document No. 455, Seventy-fifth Congress, second session, and authorized by the Flood Control Act approved June 28, 1938, are under construction at the present time by the Engineer Department (see Paragraph 5 c). Experience gained as a result of the work performed in construction of local improvements and of further detailed investigations made in connection with final designs indicates that foundation conditions for the flood walls and levees are much more serious than originally contemplated, thereby necessitating extensive treatment to prevent seepage, and requiring a more costly type of construction. It has also been found advisable to make certain modifications in alinement of the levees including the change at Hartford outlined in Paragraph 49 a below and the change at East Hartford recommended in Senate Document No. 32, Seventy-sixth Congress, first session, and to raise the grade of walls and levees along the lower reaches of tributaries. The need for this last-mentioned change was demonstrated by the unprecedented flood stages on the tributaries during the flood of September 1938. The approximate total cost to the United States for construction of the seven local improvements as revised herein is estimated at $17,000,000. The authorized project for these seven levee projects provides for the expenditure of $11,524,000. The description of these projects is given in the following paragraphs. A more detailed explanation of the status of this work and the changes proposed is given in Section 6 of the Appendix.

a. Hartford, Connecticut.

(1) Present status. - The report project proposed 27,500 linear feet of earth levee and concrete wall extending along the Connecticut River from Windsor Avenue in the north to the existing Colt Dike in the south. It included raising the existing Colt and Clark Dikes, and the construction of walls along the Park River to high ground. Protection

of the North Meadows and Riverside Park areas is nearing completion. Enlargement of the South Meadows Levee is completed except for a small section now being built as a hired labor unit. A section of the Connecticut River Levee and the Park River Conduit remain to be constructed.

(2) Change in alinement. - It is proposed to change the alinement at the South Meadows steam-electric station of the Hartford Electric Light Company to include this plant, the principal source of electrical energy for the City of Hartford, within the protected area. After the 1936 flood, and prior to the 1938 flood, the company had constructed its own protection, which proved to be inadequate in the 1938 flood. The proposed alinement will increase only slightly the total length of protection, but will involve construction of 2,900 linear feet of new earth levee and concrete wall, and a pumping station, whereas the old plan consisted of the raising and strengthening of about the same length of existing earth levee. The total additional cost to the United States is estimated at $252,000.

(3) Costs. - The revised estimated cost to the United States of construction at Hartford is $5,824,000.

(4) Local option. - The levee grades authorized in House Document No. 455 are based on the combined protection of levees and the comprehensive system of 20 reservoirs. The City of Hartford desires immediate protection against a maximum flood and has requested that the levees be built from 5 to 6 feet higher than authorized in the Federal project. Hartford also desires a pressure conduit instead of flood walls in the lower reaches of the Park River. For both of these items, the city will bear the additional expense, approximately $3,000,000 to $5,000,000.

b. East Hartford, Connecticut.

(1) Approved project. - The original alinement begins at high ground in the vicinity of the New York, New Haven and Hartford Railroad

near the north side of the town. The levee follows the Connecticut River to the Hockanum River, thence up the Hockanum to high ground at Brewer Lane at the south side of the town. The total length of the levee is approximately 17,000 feet. A long stretch of the levee and wall paralleling the Connecticut River is under construction; a short portion of this has been completed. No work has been done on the northern and southern sections of levee which extend from the river back to high ground, nor on the three pumping stations.

(2) Proposed extension. - A substantial change of alinement to include a populated area along the bluff, from the railroad north to Green Terrace, was requested by the town after it was again flooded by the 1938 flood. This change was subsequently recommended to Congress in Senate Document 3[illegible], 76th Congress, 2d Session. The increase in cost due to this change, based on the unit prices used in House Document No. [illegible], was estimated at $249,000.

(3) Costs. - The revised estimate of total cost to the United States, to complete the protection works at East Hartford, including the extension, is $2,407,000.

c. Springfield, Massachusetts. - The original alinement extends from the North End Bridge to the high ground north of the Boston and Albany Railroad bridge and from the Memorial Bridge to the South End Bridge. Above the North End Bridge, an existing levee, built to design grade, ties into high ground to the north. Mill River is carried in a pressure conduit. This protection is complete except for one small pumping station and the Mill River Conduit. The revised estimate of total cost to the United States of the protection works at Springfield is $1,118,000.

d. West Springfield, Massachusetts. - The original levee alinement begins at high ground south of the Memorial Bridge, runs south

along the bank of the Connecticut River to the mouth of the Westfield River, and thence west along the bank of the Westfield River to high ground 3,000 feet above the Agawam Bridge. At the time of resumption of flood control work after the 1938 flood, the protective works completed at West Springfield consisted of earth levees and walls extending south from a point north of the North End Bridge, along the Connecticut River and up the Westfield (Agawam) River to a point 3,000 feet north of Agawam Bridge. The levees and walls had been constructed by W.P.A. funds to a grade 2 feet lower than the grade recommended for earth levees by the Board of Engineers for Rivers and Harbors in House Document No. 455. A length of 6,100 feet of this earth levee running east from the Agawam Bridge along the Westfield River had subsequently been raised 2 feet by the United States, also as a work relief project, in accordance with these recommendations. The remaining work includes foundation treatment for an otherwise completed section of levee, construction of pumping stations, repair work, and the enlarging of two sections of levee having a total length of 7,500 feet. The revised total cost to the United States of the protection work at West Springfield is estimated at $1,502,000.

e. Chicopee, Massachusetts. - The original alinement begins at high ground in the Willimansett section, proceeds southerly along the bank of the Connecticut River to the mouth of the Chicopee River, and thence easterly to high ground beyond the Boston and Maine Railroad. On the south bank of the Chicopee River the levee begins at the lower dam, runs westerly along the Chicopee River to a short distance below the Boston and Maine Railroad, and thence southerly and easterly to high ground. A major section of the levees is completed and another is under construction. The levees on the south bank of the Chicopee River, and the pumping stations, are yet to be built. The revised total cost to the United States of the protection work at Chicopee is estimated at $2,188,000.

f. Holyoke, Massachusetts. - The protection work consists principally of a concrete flood wall, the first section of which extends from high ground below the Holyoke Dam downstream to high ground near Mosher Street. This unit is now nearing completion under contract, except for a small section near the Holyoke Dam that was completed by hired labor. The protection for the southern part of Holyoke begins at high ground at Appleton Street and runs along the river bank until it joins the existing Springdale Dike. Work on the downstream section has not yet been initiated. The revised cost to the United States of the protection work at Holyoke is estimated at $2,713,000.

g. Northampton, Massachusetts. - An alternate alinement was given in House Document No. 455 to the proposed alinement, and was not selected because of higher estimated costs. A later estimate indicated that it would cost no more than the basic plan, and as it was preferred by local interests, the alternate alinement was adopted for construction. The alinement extends from Pomeroy Terrace and Hancock Street directly across the Mill River to the intersection of the Boston and Maine Railroad with the existing lower level, thence along the existing levee to high ground. The flow from Mill River is diverted into the Connecticut River through Oxbow Lake by a diversion canal. Construction of the levee along the Connecticut River is nearing completion, except for a short section where the pumping station will be built. The diversion canal is essentially complete, except for a masonry drop structure now under construction. A levee and wall along Mill River near West Street above the point of diversion is also under construction. The total cost to the United States of the protection works at Northampton is now estimated at $1,248,000.

50. ADDITIONAL LOCALITIES STUDIED. - In addition to the levees discussed above, many other possible levee sites have been studied. Some

of these have been dismissed after preliminary examination only, while more detailed investigations of the remainder have been made. A discussion of the sites in the latter classification follows.

a. Windsor, Vermont. - The Town of Windsor, Vermont, population 3689, is located on the right or west bank of the Connecticut River 55 miles north of the Massachusetts-Vermont state line. Several factories and homes and the Boston and Maine-Central Vermont Railway are subject to inundation by floods of the magnitude of that of March 1936. Protection for this area could be provided by an earth levee and concrete wall built to design grade. Four stop-log structures and three pumping stations would be necessary. The total average annual benefits which could be realized by complete flood control protection of the area would be $31,000. The total average annual benefits after the reservoirs of the Revised Comprehensive Plan that could be realized by the proposed levee and wall are $2700. The total average annual costs would be approximately $75,000. The ratio of benefits to costs after the reservoirs is 0.04. A project for local protective works is not economically justified and will not be considered further. The area concerned would receive a large measure of protection from the reservoirs of the Revised Comprehensive Plan, which would lower the stage of a flood equal in magnitude to that of March 1936 by 15 feet.

b. Hatfield, Massachusetts. - Hatfield is located on the right or west bank of the Connecticut River three miles north of Northampton. An area including residences, a few stores, and market gardens is subject to frequent flooding. At various times prior to 1938, state and local agencies have built sections of levee until protection up to within two feet of the grade of the flood of March 1936 was provided. Portions of this levee were destroyed in the flood of September 1938 and have since been rebuilt. Protection to the design grade could be provided for this

area by increasing the height of the existing levee and changing its alinement at its southern end. Three pumping stations and one stop-log structure would be necessary. The total average annual benefits which could be realized by complete flood control protection of the area would be $17,600. The total average annual benefits after the reservoirs of the Revised Comprehensive Plan that could be realized by the proposed levee are $2900. The total average annual costs would be approximately $26,000. The ratio of benefits to costs after the reservoirs is 0.11. This project is not economically justified and will not be considered further. The area concerned would receive a large measure of protection from the reservoirs of the Revised Comprehensive Plan which would lower the stage of a flood equal to that of March 1936 by 0.6 feet.

c. Hadley, Massachusetts. - Hadley is located on the left or east bank of the Connecticut River opposite Northampton, on the peninsula formed by a meander of the river. During severe floods this entire peninsula is inundated. An existing levee has been constructed on the northern side of the peninsula to an elevation of 130 feet above mean sea level, less than a foot lower than the grade of the 1936 flood. To protect Hadley adequately, it would be necessary to raise the height of this levee to design grade and extend its southern end south and then west, almost completely encircling the village. Four pumping stations and four stop-log structures would be necessary. The total average annual benefits which could be realized by complete flood control protection of the area would be $7400. The total average annual benefits after the reservoirs of the Revised Comprehensive Plan that could be realized by the proposed levee are $700. The total average annual costs would be approximately $44,000. The ratio of benefits to costs after the reservoirs is 0.02. This project is not economically justified and will not be considered further. The area concerned would receive a large measure

of protection from the reservoirs of the Revised Comprehensive Plan, which would lower the stage of a flood equal in magnitude to that of March 1936 by 8.6 feet.

d. Northampton, Massachusetts. - A study has been made to determine the feasibility of an extension of the approved levee project at Northampton to include an area of 3/4 of a square mile to the northeast of the approved project. This extension would provide protection to the LaFleur Airport, the Northampton School for Girls, the Three County Fair grounds, the J. [illegible]. Persons and Sons Company, manufacturer of farm machinery and supplies, and about 30 homes, all of which were inundated by the floods of 1927, 1936, and 1938. A levee to protect this area would be two miles in length. It would consist of an earth embankment to the design grade, with two pumping stations and one stop-log structure. The total average annual benefits which could be realized by complete flood control protection of the area would be $17,800. The total average annual benefits, after the reservoirs of the Revised Comprehensive Plan, which could be realized by the proposed levee are $8700. The total average annual costs would be approximately $36,000. The ratio of benefits to total costs after the reservoirs is 0.24. Two other plans of levee protection were considered, protecting smaller portions of the same general area. None of these plans is economically justified and protection for this area will not be considered further. The area concerned would receive a large measure of protection from the reservoirs of the Revised Comprehensive Plan, which would lower the stage of a flood equal in magnitude to that of March 1936 by 11.2 feet.

e. Easthampton, Massachusetts. - Easthampton is a town with a population of 10,486, located on the right or south bank of the Manhan River three miles above its mouth. Broad Brook feeds Lower Mill Pond, from which water is drawn by the Hampton Company. The tailrace from the

mill to the Manhan River follows the natural course of Broad Brook at an elevation not greatly in excess of that of the Oxbow. Flooding of the mill building occurs from backwater from the Connecticut River. The railroad embankment of the Easthampton Branch of the Boston and Maine Railroad encircles the downstream side of the mill property. Protection could be furnished to the mill building by placing an impervious blanket on the downstream side of the railroad embankment, which exceeds the design grade in elevation, and closing the existing bridge over Broad Brook. This in turn would necessitate raising the dam at Lower Mill Pond and building a short pressure conduit to carry the spillway discharge of Lower Mill Pond to below the railroad embankment. The total average annual benefits which could be realized by complete protection of the area would be $8000. The total average annual benefits, after the reservoirs of the Revised Comprehensive Plan, that could be realized by the proposed improvement are $1400. The total average annual costs would be approximately $12,000. The ratio of benefits to costs after the reservoirs is 0.12. This project is not economically justified and will not be considered further. The area concerned would receive a large measure of protection from the reservoirs of the Revised Comprehensive Plan, which would lower the stage of a flood equal in magnitude to that of March 1936 by 11.2 feet.

f. South Hadley Falls, Massachusetts. - South Hadley Falls is located on the left or east bank of the Connecticut River opposite Holyoke. A church, several commercial blocks, and 30 or 40 homes are subject to inundation by a flood of the magnitude of that of March 1936. A slightly larger flood would inundate the high school, the town hall, and many additional homes. There is an existing concrete wall at South Hadley Falls constructed to the grade of the flood of March 1936. However, this wall was built solely to prevent erosion and exclude flood

debris. Its foundations are unstable and it is not designed to serve as a levee, having frequent apertures to admit water to balance the hydrostatic pressure on each side of the wall. There is no provision to exclude backwater from Buttery Brook. Protection for this area would require completely rebuilding the existing wall and raising it to the design grade; a small dam on Buttery Brook 1500 feet northeast of its Main Street Bridge to serve as an intake pool for a pressure conduit to pass the flow of Buttery Brook outside of the levee area; and a pumping station to remove local run-off from the protected area. The total average annual benefits which could be realized by complete flood control protection of the area would be $6800. The total average annual benefits, after the reservoirs of the Revised Comprehensive Plan, that could be realized by the proposed improvement are $200. The total average annual costs would be approximately $31,000. The ratio of benefits to costs after the reservoirs is 0.01. This project is not economically justified and will not be considered further. The area concerned would receive a large measure of protection from the reservoirs of the Revised Comprehensive Plan, which would lower the stage of a flood equal in magnitude to that of March 1936 by 12.2 feet.

2. Springdale, Massachusetts. - Springdale is the area adjoining the existing levee project at Holyoke, Massachusetts, on the south. After the flood of November 1927 a levee 1600 feet long, protecting an area of 122 acres, including three large factories, apartment buildings, stores, and a playground, was built by the City of Holyoke to the grade of this flood. After the flood of March 1936 this levee was enlarged and extended to the grade of the latter flood by the City of Holyoke, as a local work relief project. This grade is 1.5 to 2.1 feet below the grade of the existing levee project at Holyoke. Elevation of the existing Springdale levee to this same design grade is desirable.

The existing levee is constructed of an homogeneous section of glacial till, well graded from silt to fine gravel, with no toe drain. It is very poorly compacted and subject to cracking and sloughing at the inside toe during floods. The foundation consists of fine saturated sand in a loose state of compaction. As these conditions render the levee unstable during floods and unreliable as protection for the area, the proposed work includes rebuilding the existing levee as well as raising it. Benefits for the proposed levee can be claimed for the entire area protected. The total average annual benefits which could be realized by complete flood control protection of the area would be $64,200. The total average annual benefits, after the reservoirs of the Revised Comprehensive Plan, that could be realized by the proposed levee are $40,400. The total and annual costs of the levee are summarized in Table XVI. The estimates are prepared on the bases that local interests will bear the costs of lands, damages, and rights-of-way, and local drainage, with all other costs being assumed by the Federal Government.

TABLE XVI

COSTS OF SPRINGDALE LEVEE

Levee construction	$286,000
Drainage and pumping	138,000
Railroad relocation	6,000
Lands and rights-of-way	18,000
Total cost	448,000
Federal cost	391,000
Non-Federal cost	57,000
Federal annual cost	19,590
Non-Federal annual cost	7,350
Total annual cost	26,940

The ratio of benefits to costs after the reservoirs is 1.50. A more detailed estimate, including plans, is given in Section 6 of the Appendix.

h. Chicopee, Massachusetts. - Studies have been made to determine the feasibility of extending the levee of the approved project at

Chicopee to include the Hampden Plant of the Turners Falls Power and Electric Company, located on the left bank of the Chicopee River at its mouth, and to include the Hampden Brewing Company near Willimansett.

(1) The Hampden Plant of the Turners Falls Power and Electric Company could be protected by a realinement of the approved earth levee built to the same design grade. The total average annual benefits which could be realized by complete flood control protection of the area would be $2600. The annual charges for a levee to include the plant would be greatly in excess of this amount. Consequently, there is no justification for extending the approved levee as outlined.

(2) The Hampden Brewing Company could be protected by a concrete wall approximately 700 feet long with portable pumping facilities and two stop-log structures. The total average annual benefits which could be realized by complete flood control protection of the area would be $1100. The total average annual benefits, after the reservoirs of the Revised Comprehensive Plan, that could be realized by the proposed levee would be $110. The cost of the wall required to protect this area would greatly exceed the resulting benefits. The plan of improvement is not justified and will not be given further consideration. The Hampden Brewing Company would receive a large measure of protection from the reservoirs of the Revised Comprehensive Plan, which would lower the stage of a flood equal in magnitude to that of March 1936 by 8.7 feet.

i Riverdale, Massachusetts. - Riverdale is located in the town of West Springfield just north of the approved levee project at West Springfield. The area subject to flooding includes over one hundred residences of considerable value, a few stores and gas stations, one small factory, two extensive nurseries, and several market gardens, extending from Bagg Brook on the south to about 1/2 mile north of Goldine Brook. The preliminary levee alinement to protect this area excludes

Goldine Brook, resulting in two separate levees. The levee north of Goldine Brook would be of earth construction 2500 feet long with two stop-log structures and one pumping station. It would be necessary to divert Schoolhouse Brook, a tributary of Goldine Brook, into the Connecticut River about 2000 feet above its mouth. The total average annual benefits which could be realized by complete flood control protection of the area north of Goldine Brook would be $5,800. The total average annual benefits, after the reservoirs of the Revised Comprehensive Plan, that could be realized by the proposed levee are $2,000. The total average annual costs would be $13,200. The ratio of benefits to costs after the reservoirs is 0.15. Protection for the area south of Goldine Brook, from Goldine Brook to Bagg Brook, could be provided by an earth levee approximately two miles long with three stop-log structures and two pumping stations. The total average annual benefits which could be realized by complete flood control protection of this area would be $27,500. The total and annual costs of the levee are summarized in the following table. The estimates are prepared on the basis that local interests will bear the costs of lands, damages, rights-of-way, and local drainage, with all other costs being assumed by the Federal Government.

COSTS OF RIVERDALE LEVEE

Levee construction	$440,000
Drainage and pumping	149,000
Lands and rights-of-way	50,000
Total cost.	639,000
Federal cost	589,000
Non-Federal cost	50,000
Federal annual cost	26,460
Non-Federal annual cost	7,040
Total annual cost	33,500

Since the total average annual benefits are substantially equal to the annual charges, the improvement is considered desirable. A more detailed estimate, including plans, is given in Section 6 of the Appendix.

j. Windsor, Connecticut. - Windsor, Connecticut, is located on the right or west bank of the Connecticut River just north of Hartford. Most of the town is on ground sufficiently high to be free from flood damage. However, there are three small sections which do suffer flood damages. The first of these extends from the northern end of the existing North Meadows levee project at Hartford northerly to a brook at Wilson. The land which would be protected by a levee at this point consists of truck gardens of high value. The reservoirs of the Revised Comprehensive Plan would reduce the total average annual damages from $4500 to $600. The cost of the levee protecting the area would greatly exceed the benefits. The second section susceptible to flood damage extends from the north side of the brook at Wilson northerly for 2000 feet to and including Barber Street and includes several truck gardens and homes. The reservoirs of the Revised Comprehensive Plan completely eliminate the total average annual damages in this zone. The third section extends from Barber Street to high ground at Palisade Avenue and includes several homes and Loomis Institute. The reservoirs of the Revised Comprehensive Plan reduce the total average annual damages from $5000 to $400. The cost of a levee to protect this area would greatly exceed the resulting benefits. None of these three projects is economically justified, and they will not be considered further.

k. Wethersfield, Connecticut. - Wethersfield is located on the right or west bank of the Connecticut River just south of Hartford. A study has been made to determine the feasibility of extending the existing project at Hartford to the south to protect Wethersfield. The area protected would include several homes and the Connecticut State Prison. A levee protecting this area would necessitate the construction of a gate structure to provide access for small boats to Wethersfield Cove. The reservoirs of the Revised Comprehensive Plan reduce the total average annual damage at Wethersfield from $6900 to $300. The costs of

the levee and necessary appurtenant structures would greatly exceed the resulting benefits. This project is not economically justified and will not be considered further.

1. Greenfield, Massachusetts. - Greenfield is located near the mouth of the Green River, a tributary of the Deerfield River, the latter joining the Connecticut River about two miles below the Green River confluence. Flooding along the lower reach of the Green River is a result of backwater caused by a combination of high stages on the Deerfield and Connecticut Rivers, and seldom, if ever, by flood flows from the Green River itself. The area subject to flooding extends from the mouth of the Green River to the dam of the Greenfield Tap and Die Company. Principal points of potential damage by flooding in this area are the Greenfield Tap and Die Company, employing between 800 and 1300 people, located on the right bank, and approximately 20 homes and a recently constructed sewage disposal plant on the left bank. Of the three places subject to flood damage, the Greenfield Tap and Die Company has experienced the greatest losses. During the past twenty-eight years, there have been three floods which have risen above the first-floor level of their plant, the plant floor being flooded to depths of 1'-1" in 1927, 9'-1" in 1936, and 4'-2" in 1938. For the 1938 flood the experienced direct losses at the Greenfield Tap and Die Company were $15,000, while on the left bank, the losses amounted to $8,200. Similar figures for the March 1936 flood are $30,000 and $25,000 respectively. The March 1936 stage at the Greenfield Tap and Die Company was 151.4; the reservoirs of the Revised Comprehensive Plan would reduce this stage to 138.0. The stage of the Design Flood, in a similar manner, would be reduced from 159.5 to 144.5. The reservoirs of the Revised Comprehensive Plan would reduce the total average annual damage of the Greenfield Tap and Die Company from $6000 to $300, while for the left bank, the reduction of

the total average annual damage would be from $2000 to $200. Protection to these areas which suffer greatest damage, by means of levees or walls, would involve costs greatly in excess of the benefits which would be realized. As protection for these areas is not economically justified on the basis of damages of record and the estimates of the necessary protective works, it will not be considered further as a project to be undertaken by this Department. A Work Projects Administration project sponsored by the Massachusetts Department of Public Works was proposed for a somewhat less costly protection. This plan was approved. This will provide protection for both banks of the Green River between points approximately at the upper and lower ends of the plant of the Greenfield Tap and Die Company. Protection for the plant will be provided in the form of buttress-type and gravity section reinforced concrete walls. Work on this project was started in May, 1940 and is to be completed during the latter part of the same year. The top of the protective works is at the maximum elevation of the March 1936 flood. While this provides protection without freeboard for a flood equal to the maximum flood of record, it will, after the completion of the reservoirs of the Revised Comprehensive Plan provide complete protection against any future flood which present studies indicate can reasonably occur.

m. Ware, Massachusetts. - The Town of Ware is located on the Ware River 25 miles northeast of Springfield and has a population of 7727. It is developed for industrial, commercial, and residential purposes along both sides of the river. A large portion of the town was inundated during the flood of September 1938. Protection can be furnished by earth levees and concrete walls, constructed to design grade. Three stop-log structures, 4 pumping stations, and 5 gate structures for existing power canals would be necessary. The total average annual benefits which could be realized by complete flood control protection of the area would be

levees and concrete walls, constructed to design grade. Three stop-log structures, 4 pumping stations, and 5 gate structures for existing power canals would be necessary. The total average annual benefits which could be realized by complete flood control protection of the area would be $67,600. The total average annual benefits, after the reservoirs of the Revised Comprehensive Plan, that could be realized by the proposed levees and walls are $54,200. The total average annual costs would be approximately $155,000. The ratio of benefits to costs after the reservoirs is 0.35. This project is not economically justified and will not be considered further. The Department of Public Works of Massachusetts is planning local protection works for moderate floods to be constructed in the immediate future.

o. Chicopee Falls, Massachusetts. - Chicopee Falls is located on the left or south bank of the Chicopee River 2-1/2 miles above its mouth. Its principal industries, the Lamb Knitting Company, the Chicopee Manufacturing Company, and the Fisk Rubber Company, are located on the bank of the river and are subject to inundation during a flood of the magnitude of that of September 1938. Protection can be furnished for this area by means of a concrete wall and some earth-embankment sections where space is available, built to design grade. Three pumping stations and 5 gate structures for existing power canals would be necessary. The total average annual benefits which could be realized by complete flood control protection of the area would be $33,900. The total average annual benefits, after the reservoirs of the Revised Comprehensive Plan, that could be realized by the proposed levee and wall are $30,100. The total average annual costs would be approximately $57,000. The ratio of benefits to costs, after the reservoirs, is 0.53. This project is not justified and will not be considered further.

2. Chester, Massachusetts. - Chester has a population of 1000 and is located on both sides of the West Branch of the Westfield River in Hampden County. During the flood of September 1938 approximately 75 homes were flooded. The flood of March 1936 was less severe being 2-1/2 feet lower in stage than the 1938 flood. There is a low existing levee around the residential section on the left bank and another low levee on the right bank below Maple Street. The levee on the left bank was washed out in the flood of September 1938. It has been rebuilt but does not tie into high ground and consequently provides protection against erosion only. Complete protection could be furnished to 50 homes, an inn, and several business establishments by constructing a levee on the left bank approximately 1000 feet long. A pumping station and stop-log structures at Main Street and Maple Street would be necessary. The total average annual damage that could be eliminated by this levee would be $800. The cost of the levee would far exceed the resulting benefits. A similar levee on the right bank would provide protection to 50 homes. The cost of this levee would be approximately the same as for the left bank and the resulting benefits would be lower. In the past, portions of the channel have been deepened to lower flood stages but the effect has been only temporary as the channel soon filled into its former level. Flood protection at Chester is not justified and will not be considered further.

3. Westfield, Massachusetts. - The City of Westfield, population 16,788, is located on the right or south bank of the Westfield River, 11-1/2 miles above its mouth. Portions of its industrial, business, and residential sections are subject to severe flooding. An earth levee with one short section of rubble wall has been constructed by local interests to provide protection for this area. The levee, however, is not of sufficient height to give protection against a major flood. Complete protection

for the area could be provided by replacing the existing levee with a combination earth levee and wall built to design grade and approximately four miles in length, with four pumping stations, two stop-log structures, and one gate structure. The total average annual benefits which could be realized by complete protection of the area are $60,200. The total average annual benefits after the one upstream reservoir of the Revised Comprehensive Plan, Knightville, that could be realized by the proposed levee and wall are $43,000. The total average annual costs, would be approximately $65,000. The ratio of benefits to costs, after Knightville, is 0.66. This project is not economically justified and will not be given further consideration. A large portion of the area is protected against minor floods by the existing earth levee which extends westward from Elm Street for 5100 feet, to Franklin Street. This levee was damaged during the flood of September 1938, although the grade of the flood was three feet below the top of the levee. Since then the levee has been repaired by riprapping where necessary, and minor channel improvements have resulted from the demolition of the dam of the Turner Falls Power and Electric Company and the removal of one highway bridge. Under present conditions, a flood 45 percent in excess of that of September 1938 will pass the levee with a one-foot freeboard. With Knightville Reservoir in operation, the stage of the flood of September 1938 would have been lowered 4.0 feet, and a flood 80 percent in excess of that of September 1938 will be modified so as to pass the existing levee with one foot of freeboard. Consequently, Knightville Reservoir and the existing levee provide protection for Westfield for all except the larger and rarer floods.

Channel Improvements

51. LOCALITIES STUDIED. - A study of the Connecticut River Watershed was made to locate all reaches where there appeared to be any natural constriction or obstruction of the flood channel. Many of those found were eliminated by preliminary economic studies. Seven localities were selected for more detailed analyses: the Mount Tom Narrows below Northampton, Massachusetts; the Pocowsic Narrows below Springfield, Massachusetts; the Middletown Narrows below Hartford, Connecticut; the Ashuelot River below Winchester, New Hampshire; the Westfield River at Agawam, Massachusetts; the Mill River at Springfield, Massachusetts; the Mad River at Winsted, Connecticut. The reduction of flood flows by the reservoirs of the Revised Comprehensive Plan will greatly reduce harmful erosion and will diminish the possible benefits from channel improvement projects.

52. MOUNT TOM NARROWS BELOW NORTHAMPTON, MASSACHUSETTS.

a. Description of reach. - The reach of river studied extends from Sunderland to Holyoke Dam, with special attention being paid to the reach from Calvin Coolidge Bridge at Northampton to Holyoke Dam, a distance of 11 miles. In the upper 5 miles of the latter portion of the reach, the flood channel is over 1-1/2 miles wide and flows with a slope of 0.4 foot per mile. Below the Oxbow outlet near Northampton the river flows through a gap in the Holyoke Range, the flood width is reduced abruptly to 1/2 mile, and for a distance of 2-1/2 miles the flood slope is about 1 foot per mile. Below this the river enters the constricted section known as Mount Tom Narrows, occupying the entire valley width of about 700 feet, and for a distance of 1-1/2 miles the flood slope is about 6 feet per mile. The constricted section ends in the pool of the Holyoke Dam.

b. Plan of improvement. - The channel constriction at the Narrows appears to be a major factor in backing flood waters up to Northampton,

since more than two-thirds of the total fall in the 11-mile reach occurs in this 1-1/2 mile constricted section. Enlargement of the flood channel through the Narrows would reduce the flood slope and lower flood stages at Northampton and points upstream. In the Flood Control Report dated March 28, 1937 (House Document No. 455, Seventy-fifth Congress, second session), a plan for enlargement of the Narrows was studied. It has been re-examined in view of new hydraulic data obtained since that date. The plan studied provides for enlargement by widening the banks and excavating to low water level, with the removal of 50,000 cubic yards of earth and 450,000 cubic yards of rock, as shown on Plate No. 111, Section 7 of the Appendix.

c. Costs and benefits. - For a flood equal to that of March 1936 the crest stage would be reduced 2.3 feet immediately above the enlargement and 1.8 feet at Coolidge Bridge, Northampton. The total cost of this enlargement is estimated at approximately $1,295,000. The total average annual cost would be approximately $70,000. The total average annual benefits, before the reservoirs of the Revised Comprehensive Plan, would be $3,200. After the reservoirs of the Revised Comprehensive Plan, the total average annual benefits would be $ 600. The ratio of benefits to costs, after the reservoirs, is 0.12. This enlargement is not economically justified and will not be given further consideration.

35. [illegible] BELOW SPRINGFIELD, MASSACHUSETTS.

a. Description of reach. - The reach of river studied extends from the foot of Holyoke Dam to the lower end of Pecowsic Narrows, a total distance of 13 miles. The flood plain is about a mile wide throughout most of this reach, but the construction of dikes on both sides of the river limits the flood width to about 1,300 feet. The average flood slope in the lower portion is about 1.0 foot per mile. In the floods of March 1936 and September 1938 this slope increased to 1.3 feet per mile

in the 2-mile section known as the Narrows. Most of the damage centers from Springfield to Holyoke will be protected by levees, which, with reservoir protection, further diminish possible benefits from a channel improvement project.

b. Plans of improvement. - Three plans of improvement have been studied. The original plan described in House Document No. 455 provides for enlarging the channel by excavation on the left bank; an alternate plan provides for enlarging the channel by excavation on the right bank; and the third plan, more extensive than either of these, provides for enlargement of the channel below the Narrows for 6 miles to Enfield Dam, as shown on Plate No. 112, Section 7 of the Appendix.

(1) Original plan. -

(a) Plan. - Reduction of the flood slope at the Narrows would lower flood levels at Springfield, Chicopee, and other areas in this reach. Such a reduction can be produced by enlargement of the flood channel at Pecowsic Point. In the Flood Control Report dated March 20, 1937 (House Document No. 455, Seventy-fifth Congress, second session), a plan for enlargement at Pecowsic Narrows was studied. It has been re-examined in view of new hydraulic data obtained since then. The original enlargement plan studied provides a minimum cross section of 46,000 square feet below the March 1936 flood level by excavating about 2,000,000 cubic yards of earth and about 500,000 cubic yards of rock. All this excavation would come from the east bank of the river.

(b) Costs and benefits. - This enlargement would have lowered the March 1936 flood 0.3 foot at Springfield and 0.15 foot at Chicopee. The total cost of this enlargement is estimated at approximately $2,170,000, with annual charges of approximately $98,000. The total average annual benefits, before the reservoirs of the Revised Comprehensive Plan, would be $70[illegible], and the total average annual benefits, after the

reservoirs of the Revised Comprehensive Plan, would be $200. The ratio of benefits to costs, after the reservoirs, is 0.01. This plan is not economically justified and will not be given further consideration.

(2) Alternate plan. -

(a) Plan. - A similar plan of lesser magnitude, which has been studied for enlargement of the west bank opposite Pecowsic Point, provides a minimum cross section of 33,500 square feet below the March 1936 flood level by excavating 200,000 cubic yards of earth, and 44,000 cubic yards of rock. This enlargement would have lowered the March 1936 flood 0.15 foot at Springfield and .07 foot at Chicopee.

(b) Costs and benefits. - The total estimated cost of the alternate plan is $193,000, with average annual charges of $9,700. The total average annual benefits, before the reservoirs of the Revised Comprehensive Plan, would be $300. There would be no benefit after the reservoirs. This plan is not justified and will not be given further consideration.

(3) Extension. - Because of the uniform flood slope below Pecowsic Point, a more substantial reduction in flood heights can be secured only by extending the channel enlargement downstream 6 miles to Enfield Dam where the slope increases sharply. This enlargement would have lowered the March 1936 flood height 1.1 feet at Springfield, and would require 2,200,000 cubic yards of excavation of rock and earth at a cost of $3,700,000. Annual cost $200,000. Since this plan requires even more excavation per foot of reduction than enlargement at Pecowsic Point only, with no corresponding increase in benefits, no further consideration was given to it.

54. MIDDLETOWN TO MARROWS BELOW HARTFORD, CONNECTICUT.

a. Description of reach. - The reach of river studied extends from Windsor Locks to Maromas, a total distance of 37 miles. In the upper

reach, extending from Windsor Locks to Hartford, the valley is more than a mile wide and most of it is flooded during great floods. At Hartford the levees now built, or under construction, restrict the flood plain to the channel width of the river. From Hartford to Gildersleeve Island the valley is wider and the flooded area is over 2 miles wide during great floods. Below Gildersleeve Island the valley gradually narrows, turns from its southerly direction to southwest, and then bends to the east at Middletown. The constricted section below Middletown is known as the Narrows. In the floods of March 1936 and September 1938, two-thirds of the total fall from Hartford to Saybrook was concentrated in the bend at Middletown and the Narrows below it. Any appreciable reduction of the flood slope in this reach would lower flood stages at Middletown, Hartford, and other damage centers throughout the reach.

b. Plan of improvement. - The topography east of Middletown is adapted to construction of a cut-off channel to carry part of the flood flow from Gildersleeve Island to Mile 28 just below the Narrows. In the Flood Control Report dated March 20, 1937 (House Document No. 455, Seventy-fifth Congress, second session) such a cut-off channel, known as the Gildersleeve Cut-off, was studied. It has been re-examined, using new hydrologic data acquired since the previous study. The Gildersleeve Cut-off would provide an auxiliary flood channel to be excavated across the bend from Gildersleeve Island to Mile 28. The total length of the excavated channel would be 4.0 miles; the corresponding river distance is 7.6 miles, as shown on Plate No. 113, Section 7 of the Appendix. The bottom width of this channel would be 600 feet at low-water elevation. A weir near the upstream end of the channel would prevent diversion of low-water flow. This channel would necessitate about 33,000,000 cubic yards of excavation (earth and rock) and would require the relocation of 3 highways, 2 transmission lines, and a railroad.

c. Costs and benefits. - For a flood equal to that of March 1936 about 32 percent of the flow would be diverted down this channel, thereby lowering the flood stage 2.7 feet at Gildersleeve Island, 1.5 feet at Hartford, and 1.1 feet at Windsor Locks. Most of the damage centers of Hartford and East Hartford are now or will be soon protected by levees. The total average annual benefits from the Gildersleeve Cut-off would be $52,700 before the reservoirs and levees of the Revised Comprehensive Plan, and $7400 after the reservoirs and levees of the Revised Comprehensive Plan. The total estimated cost of this cut-off is estimated at $20,350,000, with annual charges of $954,000. The ratio of benefits to costs, after the reservoirs, is 0.01. It is not economically justified and will not be considered further.

d. Alternate plan of improvement. - No serious consideration has been given to the possibility of excavating only a pilot channel and thereafter depending on future floods to scour out an adequate channel although such a scheme has been proposed. It would probably take several great floods to scour such a channel before it became effective, and since the navigable channel from Middletown to the mouth, now maintained by dredging, would be injured as a result of each flood, no value is attached to this pilot channel alternative.

55. ASHUELOT RIVER BELOW WINCHESTER, NEW HAMPSHIRE.

a. Description of reach. - The reach of river studied extends from the Lawrence Leather Company Bridge above Winchester to the broken dam of the New Hampshire Public Service Company below Ashuelot, a total distance of 3.5 miles. Through the upper 2-1/2 miles of the reach studied, the river flows through several meanders with a flood slope of two feet per mile, in a flood plain about half a mile wide. In the last mile, from the Boston & Maine Railroad bridge to the village of Ashuelot, the river is relatively straight and flows with a flood slope of twelve feet per mile.

b. Plan of improvement. - In the floods of March 1936 and September 1938, severe flood losses occurred in Winchester at the head of this reach. Any reduction in the flood slope between the railroad bridge and the broken dam of the New Hampshire Public Service Company would lower flood stages at Winchester. Removal of the broken dam and excavation of the channel through Ashuelot would effect such reductions. The plan of improvement provides for enlargement of the flood channel at the railroad bridge and through the Town of Ashuelot. The enlargement would provide a uniform trapezoidal cross section having a bottom width of 125 feet and 1-on-2 side slopes. It would require excavation of 42,000 cubic yards of earth and boulders at the railroad bridge and 68,000 cubic yards of earth and boulders at Ashuelot. The broken dam of the New Hampshire Public Service Company, located 500 feet below the highway bridge, would be completely removed. Details are shown on Plate No. 114, Section 7 of the Appendix.

c. Costs and benefits. - This improvement would provide a reduction in the stage of a flood similar to that of September 1938 of 1.6 feet at Winchester. The total cost of the plan is estimated at $163,000 with annual charges of $8300. The total average annual benefits, before the reservoirs of the Revised Comprehensive Plan, would be $12,000 and, after the reservoirs, $2800. The ratio of benefits to costs, after the reservoirs, is 0.34. This plan of improvement is not justified and will not be given further consideration. Winchester will receive substantial protection from the three reservoirs of the Revised Comprehensive Plan located on the upper Ashuelot Watershed.

56. AGAWAM, MASSACHUSETTS. - Agawam is located on the right or south bank of the Westfield River near its mouth. Walnut Street extends for several hundred feet along the top of a high bank within a few feet of the river, just above the Agawam Bridge. Farther upstream several

homes and garages are located between Walnut Street and the river. These houses and Walnut Street itself are well above maximum flood levels, but are endangered by progressive erosion of the high steep bank of the river. This erosion has been occurring over a period of many years and is in no way the result of diversion of currents by recent levee projects at West Springfield. Protection for the area could be furnished only by a high wall or by riprapping the bank of the Westfield River. In this area, however, the cost of this work would be greatly in excess of the value of the property protected. As such a project cannot be economically justified, it will not be considered further.

57. MILL RIVER AT SPRINGFIELD, MASSACHUSETTS.

a. Description of reach. - The reach of the river studied extends from the upstream end of the existing Mill River conduit project at the Bay State Thread Company Dam, located approximately 1700 feet above the confluence of the Connecticut and Mill Rivers, to the United States Arsenal Dam, about a mile upstream. The difference in crest elevation between the two dams is approximately 80 feet. Three other dams and four bridges are located in this reach. The river is generally narrow with high banks. There is little storage in the pools of the dams. Under existing conditions the river channel cannot carry 4300 cubic feet per second, the design flood selected for the Mill River conduit, without overflowing its banks. At three isolated points along the Mill River, viz., at Belmont Avenue Bridge, Bay State Thread Company Dam, and Springfield Waste Company Dam, such a flood would overflow the banks and inundate portions of the City of Springfield. The topography is such that water leaving the Mill River would not return to it, but would flow down various streets to the center of Springfield, which is situated along the low flood plain of the Connecticut River. The otherwise complete protection of Springfield against flooding from the Connecticut River would thus be jeopardized.

b. Plan of improvement. - The proposed work, as shown on Plate No. 115, Section 7 of the Appendix, will eliminate the hazard, as follows:

(1) Belmont Avenue Bridge. - The capacity of the Belmont Avenue Bridge, under existing conditions, is limited to approximately one-fifth of the design discharge. Additional carrying capacity under the bridge is necessary. This could best be attained by enlarging the opening or giving an additional span. This would require a new bridge or practically complete reconstruction. The cost would be excessive. An alternate improvement is to increase the velocity through the bridge by increasing the head above by means of wing walls and lining the bridge opening to withstand the higher velocity. This method is recommended. The total cost under this scheme is estimated at $25,000.

(2) Bay State Thread Company Dam. - The proposed work at Bay State Thread Company Dam includes reinforced concrete walls, reinforced concrete facing of existing building walls, and the reconstruction of the headgate at a total estimated cost of $22,000.

(3) Springfield Waste Company Dam. - The proposed work at Springfield Waste Company Dam includes reinforced concrete walls, a stop-log structure, and reinforced concrete facing of an existing building wall at a total estimated cost of $4000.

c. Costs. - The cost of lands, damages, and rights-of-way should be borne by local interests. All other costs should be borne by the Federal Government. The cost of this improvement is summarized in Table XVII.

(Table on following page)

TABLE XVII.

COST OF MILL RIVER IMPROVEMENT

Construction	$ 49,000
Lands and rights-of-way	2,000
Total cost	51,000
Federal cost	49,000
Non-Federal cost	2,000
Federal annual cost	2,430
Non-Federal annual cost	780
Total annual cost	3,210

d. Conclusions. - This work is considered necessary since the levee system at Springfield will not provide complete protection to Springfield unless flooding from the Mill River is eliminated.

58. LINSTED, CONNECTICUT.

a. Description of reach. - The reach studied extends upstream from Clock Shop Dam on the Still River (drainage area 42 square miles) to Lake Street Bridge on the Mad River, a total distance of about two miles. Clock Shop Dam, crest elevation 687.5, controls flood elevations as far upstream as the confluence of the Mad and Still Rivers. None of the three bridges that cross the Still River in this reach augments flood stages. From the confluence of the rivers upstream to Lake Street Bridge, Mad River rises 46 feet in a distance of 6200 feet. In much of this reach the river is confined between walls only 40 to 50 feet apart. Overhanging houses and garages encroach on even this narrow space and in five cases buildings completely bridge the stream. Two unused dams, five low bridges, and a debris-filled channel aggravate the flood hazard in this reach. The flood problem is not serious on the Still River; the Gilbert Clock Company appears to be the item most likely to suffer flood damage and it has suffered so little in past floods that no steps have been taken to install flashboards or flood gates. From the confluence of Mad and Still Rivers to Lake Street flood damages have been more serious because of the previously mentioned encroachments on the stream bed. In at least two cases

of record, 1927 and 1938, flood waters escaped into Main Street at a point just above the constriction caused by Winsted Motor Sales Garage, causing considerable damage. Three of the five dams located on this reach of river in 1938 have been removed, thereby lessening the flood hazard in their vicinity but the channel is so choked that each bridge and building across the stream remains a potential damage point.

b. Plan of improvement. - Plans of improvement which have been studied include flood control storage, diversion, and channel improvements. For storage, the possibility of increasing the capacities of Highland Lake and Crystal Lake, both upstream of Winsted, has been investigated. However, the contributing drainage areas to these two lakes is only 7 square miles and the water area of the lakes, in excess of one square mile, already provides sufficient storage to modify flood flows from their own drainage areas. The tunnel connecting the two lakes to Mad River was designed for water supply, and is of insufficient capacity to carry any appreciable flood flows. Diversion of flood waters from the Mad River to these lakes would require a sidehill canal approximately one mile long, the cost of which would be prohibitive. Examination of topography above Winsted reveals no site on the Mad River suitable for a flood control reservoir. It would be possible to divert flood flows from the Mad River to the Still River by a tunnel, materially reducing flood flows in the present natural channel of Mad River through the center of Winsted. The topography and the available head would favor the selection of a pressure conduit 4400 feet long and an open cut 1600 feet long for this diversion. This diversion would provide complete protection to those portions of Winsted on the Mad River but the cost would far exceed the benefits. Channel improvements have been studied to provide lowering of flood crests on both the Mad and Still Rivers. To facilitate the study of channel improvements, the reaches subject to flooding have been divided into two zones, each one being studied independently.

(1) Zone A. - Zone A extends along the Still River from the dam of the W. L. Gilbert Clock Company to the mouth of the Mad River, thence along the Mad River to the Case Avenue Bridge. Flood stages in this zone can be lowered by excavating a trapezoidal channel with an average bottom width of 25 feet and side slopes of 1 on 3 along the present channel, and lowering the crest of the Gilbert Dam four feet and installing flashboards to maintain the present pool level, all as shown on Plate 116 of the Appendix. This channel excavation would be so located that no underpinning of existing walls would be necessary. One 2-1/2 story frame building would be removed and a short section of wall rebuilt. The existing alinement of Mad River, at the bend near the foot of Walnut Street, would be straightened. This improvement would lower the stage of a flood equal in magnitude to that of September 1938 approximately six feet. The resulting average annual benefits would be $1900. The total estimated cost of the improvement is $169,000, with annual charges of $11,600. The ratio of benefits to costs is 0.16. It is therefore not economically justified and will not be considered further.

(2) Zone B. - Zone B extends along the Mad River from the Case Avenue Bridge to Lake Street. The capacity of the channel can be increased by the removal of the Maden and Kelley Company Dam and the New England Knitting Company Dam, and the excavation of a trapezoidal channel with an average bottom width of 25 feet and 1-on-3 side slopes, as shown on Plate No. 116, Section 7 of the Appendix. No underpinning of existing walls would be necessary. The underpinning of one large warehouse would have to be improved. This channel improvement would lower the stage of a flood equal in magnitude to that of September 1938 11-1/2 feet. The total average annual benefits from the improvements in this zone would be $12,000. The total estimated cost of the improvement is $137,000, with

annual charges of $8600. The ratio of benefits to costs is 1.40. The cost of this improvement to Zone B is summarized in Table XVIII below. Local interests should bear the cost of lands, damages, and rights-of-way. Local interests have indicated informally that a portion of the cost might be provided by them although, due to other municipal construction, funds are not immediately available by the town.

TABLE XVIII

COST OF PLAN B, WINSTED

Construction	$134,000
Lands and rights-of-way	3,000
Total cost	137,000
Federal cost	134,000
Non-Federal cost	3,000
Federal annual cost	5,700
Non-Federal annual cost	2,900
Total annual cost	8,600

c. Conclusions. - Flood Control protection for the City of Winsted by means of diversion or flood control storage cannot be justified. Protection by means of channel improvements is justified in Zone B.

VIII. CONNECTICUT AND CHICOPEE RIVERS, MASSACHUSETTS

59. GENERAL. - The Chicopee River Watershed lies east of the Connecticut River in the central part of Massachusetts. The Chicopee River empties into the Connecticut River at Chicopee, between Holyoke and Springfield, Massachusetts. The total drainage area is 721 square miles, of which 210 square miles are contributed by the Quaboag, 221 by the Ware, and 216 by the Swift River. In general the watershed is very hilly, with many lakes and narrow river valleys. All the principal cities are located in the valleys of these rivers. The Chicopee River is formed near Three Rivers, Massachusetts, at the confluence of the Swift, Ware, and Quaboag Rivers. From Three Rivers the Chicopee River flows west 17.2 miles through a narrow valley to its junction with the Connecticut River at Chicopee, Massachusetts. Above Three Rivers the watershed is roughly rectangular in shape, the length north and south being about 30 miles, and the width east and west about 24 miles. The Swift River flows south from Minsor Dam 9.3 miles to the Chicopee River at Three Rivers, Massachusetts, and drains the western portion of the rectangular watershed. The Ware River has its source in several ponds in the Town of Hubbardston, Massachusetts, near Mount Wachusett, and drains the central portion of the rectangular watershed. From the diversion dam of the Metropolitan District Water Supply Commission at Coldbrook, Massachusetts, the Ware River flows southwest 27.8 miles to its junction with the Swift 0.7 of a mile above Three Rivers, Massachusetts. In general the valley is narrow with many steep tributaries entering from both sides, tending to increase the peak flood discharges. The principal cities in the Ware River Valley are Gilbertsville, Ware and Thorndike. The Quaboag River has its source in several ponds in the Towns of Brookfield and North Brookfield, and drains the southern portion of the rectangular watershed. From its source

to the town of West Brookfield, a distance of approximately 5.2 miles, the Quaboag River flows through a flat swamp section known as the Brookfield Flats. From West Brookfield the Quaboag River flows west 17.8 miles to its junction with the Chicopee River at Three Rivers, Massachusetts. The principal towns in the Quaboag River Valley are East Brookfield, Brookfield, West Brookfield, Warren, West Warren, and Palmer. A map showing the location of the Chicopee River is shown on Plate No. 1 of this report, and profiles of the main stream and the principal tributaries are shown on Plate No. 131, Section 8 of the Appendix.

60. RAILROADS. - The double track main line of the Boston and Albany Railroad follows the valley of the Chicopee and the Quaboag Rivers, with a branch line on the Ware River. The Central Vermont Railroad crosses the lower portion of the watershed via the valleys of Conants Brook and the Swift River. The Boston and Maine Railroad follows the valley of the Ware River.

61. WATER SUPPLY. - Large portions of the drainage areas of the Swift and Ware Rivers have been utilized by the Metropolitan District Water Supply Commission of the Commonwealth of Massachusetts to furnish water for Metropolitan Boston. Winsor Dam is practically completed at the present time and filling of the reservoir began in the summer of 1939. The dam is located on the Swift River above West Ware, creating a reservoir 18 miles long with a water surface of 38.6 square miles and a watershed area of 185.9 square miles. The capacity of the reservoir to spillway crest is 1,273,200 acre-feet, or 129 inches of run-off on the watershed area. The Quabbin Reservoir, Elevation 530.0, Boston City Base, is connected to the Wachusett Reservoir, Elevation 395.0, Boston City Base, by the Quabbin Aqueduct, a tunnel 11 feet wide, 12.9 feet high, and 24.6 miles long. At the Ware River diversion dam and intake at Coldbrook, elevation 656.0, Boston City Base, water may be diverted from 96.8 square

miles of the Ware River watershed to Quabbin Reservoir or to Wachusett Reservoir by means of the same Quabbin Aqueduct.

62. COMMERCIAL STATISTICS. - The watershed is highly developed industrially, with all the principal industries located along the river. Table XIX gives statistical data on the most important industrial centers in the area. These data are for the year ending November 30, 1937, and are published by the Department of Labor and Industries of the State of Massachusetts. It may be noted that the value of the finished products for the year 1937 is about $20,000,000 greater than for the year 1934. Of the present installed power, 55 percent is used directly in the manufacture of textile and paper products, 43 percent being developed at hydroelectric plants and used for industrial and domestic purposes.

TABLE XIX. INDUSTRIAL DATA

Town	Number of plants	Value of stock and materials	Amount of wages	Average number of employees	Value of products
Chicopee	53	$25,548,947	$9,022,257	7,641	$46,209,387
North Brookfield	5	720,291	354,727	434	1,329,150
Palmer	19	1,813,662	1,064,741	1,017	4,863,347
Spencer	11	3,683,306	1,548,215	1,655	6,099,849
Ware	16	3,669,909	1,247,297	1,485	6,397,663
Warren	6	1,493,308	633,450	675	2,888,915
Totals	110	36,929,923	13,870,687	12,907	67,788,311

63. AGRICULTURAL STATISTICS. - Statistics regarding farms and farm products for the counties covered in part by the watershed, as derived from the Federal Census of 1930, are given in Table XX. These data are prorated in the same proportion as the area of each county within the watershed is to the total area of that county.

TABLE XX. AGRICULTURAL STATISTICS

Item	Counties			
	Franklin	Hampden	Hampshire	Worcester
Area in farms - acres	15,260	44,340	50,530	104,920
Value of crops	$195,700	$606,800	$842,980	$813,670
Value of livestock	41,350	105,960	155,820	374,450
Total value of farm products	365,620	1,219,820	1,519,650	3,142,000

64. POPULATION. - Table XXI shows the population of the watershed by counties, according to the 1935 Census by the State of Massachusetts.

TABLE XXI. POPULATION BY COUNTIES

County	Area within watershed in square miles	Approximate population within watershed
Franklin	48.6	735
Hampden	140.3	78,349
Hampshire	129.7	11,194
Worcester	401.4	27,059
Totals	720.0	117,337

65. FLOOD LOSSES OF RECORD. - The Chicopee River Valley suffered extensive damage in the recent major floods of March 1936 and September 1938. Records of damage from previous floods are not available.

a. March 1936. - The flood of 1936 exceeded the previous maximum flood of record by 3 to 5 feet in stage, causing direct losses totaling $1,207,000, of which 50 percent was to highways and bridges. Much of this latter damage would not be recurring because of betterments made in repairing and reconstructing the highways and bridges. Losses on the Swift River were moderate. Damage on the Quaboag River was not severe because it is not highly developed industrially. The Ware River was the most severely affected with the industrial and urban centers of Barre, Ware, and Thorndike sustaining losses of $617,000. Only at Ware

were any large residential sections flooded.

b. September 1938. - The flood of September 1938 reached stages several feet higher than the 1936 flood, except on the Swift River where the flood was modified by Quabbin Reservoir. Only two highway bridges in the entire valley remained passable. Damage was particularly severe on the Ware River in the villages of Ware, South Barre, Barre Plains, Wheelwright, Gilbertsville, and Thorndike. The Town of Ware sustained the greatest losses with 4 industrial plants, several stores, and 200 homes being flooded. Damage in the Ware River Basin alone totalled over $2,000,000. On the Quaboag River a few mills and several farms were inundated resulting in a total direct loss of approximately $1,000,000. On the main stem of the Chicopee River heavy losses were experienced at Three Rivers, North Wilbraham, Ludlow, Chicopee Falls, and Chicopee. The total flood losses of September 1938 in the Chicopee Watershed were $4,546,000.

66. AVERAGE ANNUAL FLOOD LOSSES. - The average annual flood losses for seven damage zones in the Chicopee Watershed were determined by the method outlined in paragraphs 15, 16, and 17. The average annual losses, by rivers, are summarized in Table II and total $2,217,600.

67. PLAN OF IMPROVEMENT. - A comprehensive flood control study of the Chicopee River and its tributaries has been made. Storage reservoirs on the Ware and Quaboag Rivers and levees at Chicopee Falls and Ware were investigated.

a. Reservoirs. - Two flood control reservoirs on the Ware River and one on the Quaboag River were considered.

(1) The West Brookfield dam site is located on the Quaboag River at West Brookfield. The most economical reservoir capacity is 6.0 inches of runoff from the drainage area of 106 square miles. It would provide protection to West Brookfield, Warren, West Warren, Palmer,

Three Rivers, North Wilbraham, Ludlow, Indian Orchard, Chicopee Falls, Chicopee, and points below Chicopee on the Connecticut River. The total estimated cost is $2,317,000, with annual charges of $123,600. The total average annual benefits which would accrue to this reservoir as one of the 29 reservoirs in the Revised Comprehensive Plan are $125,200, of which $27,600 would be tributary benefits.

(2) The Barre Falls dam site is located on the Ware River at Barre Falls just below the junction of the two branches of the Ware River. The most economical reservoir capacity is 8.0 inches of runoff from the drainage area of 57 square miles. It would provide protection to Barre Plains, Gilbertville, Ware, Thorndike, Three Rivers, North Wilbraham, Ludlow, Indian Orchard, Chicopee Falls, Chicopee, and points below Chicopee on the Connecticut River. The total estimated cost is $965,000, with annual charges of $53,000. The total average annual benefits which would accrue to this reservoir as one of the 29 reservoirs in the Revised Comprehensive Plan are $101,900, of which $46,600 would be tributary benefits.

(3) The Thorndike dam site is located on the Ware River one mile above the upper dam of the Thorndike Company at Thorndike in the Town of Palmer. The drainage area is 214 square miles. It would provide protection for Thorndike, Three Rivers, North Wilbraham, Ludlow, Indian Orchard, Chicopee Falls, Chicopee, and points below Chicopee on the Connecticut River. Extensive levees at Ware, Massachusetts would be necessary to protect the town from the backwater of the dam.

b. Levees. - In addition to the above described reservoirs, levees were considered at two potential damage centers, Ware River at Ware and Chicopee River at Chicopee Falls.

(1) The feasibility of levees to design grade on both banks of the Ware River at Ware was investigated. The results of this

investigation are discussed in paragraph 50 n.

(2) The feasibility of a levee to design grade on the left bank of the Chicopee River at Chicopee Falls was investigated. The levee would protect the area from the dam of the Chicopee Manufacturing Company approximately one mile downstream to a point below the Fisk Rubber Company. The results of this investigation are discussed in paragraph 50 o.

68. EFFECT OF QUABBIN RESERVOIR ON FUTURE FLOODS. -Quabbin Reservoir in its normal condition will be full to spillway crest, and inasmuch as that is the most severe condition from the standpoint of flood control benefits, that condition was assumed for all flood control studies. If Quabbin Reservoir is filled to spillway crest, it is presumed that the Metropolitan District Water Supply Commission would not divert flood water from the Ware River into Quabbin Reservoir, although some flood control effect would be obtained by the resultant surcharge storage above the Winsor spillway crest, amounting to 2.8 inches of run-off on the drainage area of 185.9 square miles for each foot of rise above the spillway crest. The discharge for one foot of head on the spillway is 1450 cubic feet per second; for two feet of head on the spillway, which corresponds to 5.6 inches of runoff on the watershed, the discharge is 4080 cubic feet per second. From a consideration of the above facts it can be concluded that even if the Quabbin Reservoir is full at the beginning of any flood, the surcharge storage will afford a very high degree of control on the drainage area of 185.9 square miles.

69. DISCUSSION. -

a. Barre Falls and West Brookfield are included as two of the 29 reservoirs in the Revised Comprehensive Plan. The total estimated cost, the annual cost and the total average annual benefits for Barre Falls Reservoir and West Brookfield Reservoir are shown in paragraphs 67 a(1)

and (2) above and the reservoirs are further discussed in paragraphs 40 and 45. The Thorndike Reservoir at spillway crest elevation would flood back into Ware and make necessary extensive levees or raising of local works now planned for Ware. The cost of such works added to the cost of the Thorndike dam make it economically unjustified, and it will not be considered further.

b. As shown in paragraphs 50 n and 50 o, levees on the Ware River at Ware and on the Chicopee River at Chicopee Falls are not justified and will not be considered further.

IX. GREEN RIVER, MASSACHUSETTS

70. GENERAL. - The Green River Watershed lies west of the Connecticut River, in the northwestern part of Massachusetts and the southern part of Vermont. The Green River empties into the Deerfield River about two miles from the Connecticut River. The total drainage area is 89 square miles, 37 square miles being in Vermont, and 52 square miles in Massachusetts. The Green River has its source in the Town of Marlboro, Vermont, and flows in a southerly direction approximately 25 miles to the Deerfield River. The Town of Greenfield, Massachusetts, is located near the mouth of the Green River. A profile of the Green River is shown on Plate No. 130, Section 8 of the Appendix.

71. RAILROADS. - There are no railroads in the main valley of the Green River. The Connecticut Division of the Boston and Maine Railroad follows Mill Brook, a tributary of the Green River, for about five miles above the Town of Greenfield. The Fitchburg Division of the Boston and Maine Railroad crosses the Green River Valley at Greenfield.

72. COMMERCIAL STATISTICS. - The only commercial center in the Green River Watershed is the Town of Greenfield. Agriculture is the principal occupation of the population of the watershed. There are no large industries located in the watershed.

73. POPULATION. - Table XXII shows the population of the towns in the region of the Green River Watershed, according to the Federal Census of 1930.

(Table on the following page)

TABLE XXII

POPULATION OF TOWNS IN THE REGION OF THE GREEN RIVER WATERSHED

Towns in Vermont	Population 1930	Towns in Massachusetts	Population 1930
Halifax	390	Deerfield	2,892
Guilford	663	Greenfield	15,500
Marlboro	255	Shelburne	1,544
		Leyden	261
		Colrain	1,391
Total	1,308		21,578
Total, Vermont and Massachusetts 1930			22,866

74. FLOOD LOSSES OF RECORD. - Damage close to the mouth of the Green River, where the principal development of the stream exists, results from backwater of the Deerfield and Connecticut Rivers. Above the limits of backwater, only minor damage is caused by overflow of the Green River and its tributaries because there is little development in the valley. Damage sustained as a result of the floods of March 1936 and September 1938 have been thoroughly investigated and form the basis for the computation of average annual losses.

a. March 1936. - The flood of March 1936 caused direct losses totaling $75,000 within the area flooded by backwater. Nearly one-half the loss was sustained by a machine tool company located on the right bank and the remainder by stores and dwellings extending approximately a mile along the left bank. On the upper river only $11,500 damage was sustained and this was principally to highways.

b. September 1938. - The Connecticut backwater crested approximately five feet lower than in 1936 and resulted in damage of $28,500 in the developed area. In the upper valley the flood was more severe and the crest of 1936 was exceeded by about one foot. Of the direct loss of $25,600 above the limits of backwater, about 80 percent was to highways

and bridges. Because of betterments made after the floods, only a portion of these losses will recur in a similar flood.

75. AVERAGE ANNUAL FLOOD LOSSES. - The average annual flood losses for the Green River were determined by the method outlined in paragraphs 15, 16, and 17. The average annual losses are summarized in Table II and total $2200, for the zone above the effect of the Connecticut River backwater. The average annual flood losses for the area affected by backwater are included in the Connecticut River Zone 7 and total $8000.

76. PLAN OF IMPROVEMENT. - Two methods of flood control for the Green River watershed have been considered in detail; a storage reservoir in the headwaters, and a levee project in the lower reach to exclude backwater from the Connecticut River.

a. Reservoirs.- One dam site located on the Green River, three miles above its mouth and just below the mouth of Allen Brook, was studied and is shown in Table VIII as Greenfield Dam Site. The most economical capacity of the reservoir would be seven inches of run-off from its drainage area of 72 square miles, providing protection to the Town of Greenfield and points on the Connecticut River below Montague City. Its total estimated cost is approximately $3,050,000, with annual charges of $157,000. The total average annual benefits which would accrue if this reservoir were added to the Revised Comprehensive Plan would be $82,200, of which $400 would be tributary benefits.

b. Levees. - Levees for those reaches of the Green River above the effect of backwater from the Connecticut River are not practicable because the damages are not concentrated. The results of the study to determine the feasibility of levees for the lower reach of the river affected by backwater are given in paragraph 50 m.

77. DISCUSSION. - Greenfield Reservoir cannot be justified for inclusion as one of the reservoirs of the Revised Comprehensive Plan. There

is no other reservoir site on the Green River which would be better adapted for flood control. As shown in paragraph 50 m, levees on the lower Green River cannot be justified, and levees elsewhere along the river are not practicable. Consequently, flood control measures on the Green River within the scope of this report cannot be justified. However, it should be noted that no damage on the Green River occurs on its lower reaches, because of the backwater effect from the Connecticut River. The 29 reservoirs of the Revised Comprehensive Plan will reduce the stage of a flood equal in magnitude to that of March 1936 by 9.6 feet. This will eliminate all damage on the lower Green River, except for the larger and rarer floods.

X. CONNECTICUT RIVER IN THE STATE OF MASSACHUSETTS BETWEEN THE HATFIELD TOWN LINE ABOVE COOLIDGE BRIDGE AND THE NARROWS AT MOUNT TOM

78. GENERAL. - Studies of the reach of the Connecticut River extending from the Hatfield town line above Coolidge Bridge to the Narrows at Mount Tom were authorized in the Flood Control Act approved August 11, 1939. (See paragraph 1 c). Flood damages in this area are suffered principally by the communities of Hatfield, Hadley, Easthampton, and Northampton, and also by the area in the vicinity of LaFleur Airport in Northampton. Flood heights in the reach between Sunderland and the Narrows are raised by backwater caused by the restricted section in the channel at the Narrows. A detailed description of the reach is given in paragraph 52 a. Flood protection for the principal section of Northampton is provided by an existing project. (See paragraphs 5 c and 49 g). A levee, constructed by State and local interests, provides protection for Hatfield up to within 2 feet of the grade of the flood of March 1936. However, the condition of this levee is such that the protection is unreliable. Hadley is also protected up to within 1 foot of the grade of the March 1936 flood by a levee constructed on the north side of the town by local agencies.

79. DEVELOPMENT. - The affected area is chiefly rural in nature and devoted to agriculture, including market gardening, the principal crops being tobacco, potatoes, carrots, and onions. Northampton and Easthampton constitute the industrial and commercial centers in the area, each possessing large textile establishments. A public utility steam power plant is also located in Easthampton.

80. RAILROADS. - A double-track line of the Boston and Maine Railroad and a single-track line of the New York, New Haven and Hartford Railroad are adjacent to the Connecticut River within the reach studied

and are subject to periodic flooding.

81. FLOOD LOSSES OF RECORD. - Damage to crops, dwellings, commercial establishments, and to a few industries is of frequent occurrence in the reach of the Connecticut River from Hatfield to the Narrows at Mount Tom. In recent years the principal flood losses have occurred in November 1927, April 1933, March 1936, May 1937, and September 1938. Losses sustained as a result of the outstanding floods of 1936 and 1938 have been thoroughly investigated and form the basis for the computation of average annual losses.

a. March 1936. - The flood of 1936 exceeded previous floods of record by a wide margin and caused direct losses of $1,724,000. Approximately 5700 acres of crop lands devoted to tobacco, potatoes, market garden, and other high-type crops were flooded and severely damaged by heavy deposits, erosion of topsoil, and gullying. Approximately 750 dwellings, located principally in the centers of the towns of Northampton, Hatfield, and Hadley, were flooded, some over the second floor. In the vicinity of Northampton several industries and a large steam plant sustained heavy losses. Commercial districts were flooded; outlying dwellings, farms, and roads were badly damaged by water and ice, and Northampton remained isolated for about one week. At Hatfield the local levee was washed out; tobacco lands were badly washed, drying sheds carried away, and heavy losses were sustained in the tobacco warehouses. The river washed out the levee at Hadley and flowed across the portion of the town that lies in a meander of the stream, flooding public buildings and dwellings a mile or more from the normal channel of the river.

b. September 1938. - The flood of 1938 crested two to three feet lower than the flood of 1936. Direct losses in the reach totaled about one million dollars less than in 1936 because of the lower river

stage, savings due to improved levees at Northampton, more efficient flood warnings, and also due to the fact that a tobacco warehouse which sustained large losses in 1936 had been relocated on high ground. Otherwise damage was very similar to that of 1936; local levees at Hatfield and Hadley were washed out; crop lands, dwellings, and a few industries were flooded. Direct losses amounted to approximately $789,000.

82. AVERAGE ANNUAL FLOOD LOSSES. - The average annual flood losses were determined from the losses of record by the method outlined in paragraphs 15, 16, and 17. Annual losses total $148,000 for the reach from Hatfield to the Narrows at Mount Tom.

83. PLAN OF IMPROVEMENT.

a. Channel improvement. - Enlargement of the Mount Tom Narrows was the subject of a study, the results of which are given in paragraph 52 c. This enlargement is not economically justified and will not be given further consideration.

b. Levees. - Consideration was given to the construction of levees for the protection of Hatfield, Hadley, Easthampton, and the area in the vicinity of LaFleur Airport in Northampton. The results of these studies are given in paragraph 50 b, c, d, and e. None of these levees is economically justified, and no further consideration will be given them.

c. Reservoirs. - Operation of the reservoirs of the Revised Comprehensive Plan would provide a large degree of protection to all localities in this reach. The stage of a flood, equal in magnitude to that of March 1936, would be lowered 11.2 feet at Northampton and 8.6 feet at Hatfield and Hadley.

84. DISCUSSION. - The reductions in flood stages by the 29 reservoirs of the Revised Comprehensive Plan are of such an amount that, in

conjunction with existing levees, only minor damages will be suffered and at rare intervals. The residual losses are mostly agricultural and are widespread, obviating the need or justification for a channel improvement project.

XI. SUMMARY AND DISCUSSION

85. NEED FOR ADDITIONAL PROTECTION. - The Connecticut Valley has been subject to frequent and severe floods, and flood control is of paramount importance for the preservation of existing values, the stability of present development, and the social security of the inhabitants. The heavy losses experienced have developed a feeling of insecurity and fear. If confidence is not restored by an adequate plan for protection, an emigration of industrial interests may ensue, and the future development of the area be retarded. A plan consisting of twenty reservoirs and levees at seven localities was recommended in the survey report printed in House Document No. 455, Seventy-fifth Congress, second session. Since the submission of that report, the occurrence of the great storm and flood of September 1938 has clearly indicated that the recommended Comprehensive Plan will not provide adequate protection for the valley. Additional control is urgently needed and justified. The justification of additional protection is based on tangible losses, neglecting loss of life and other extensive intangible losses of importance. Although the comprehensive plan described in House Document No. 455 provides for twenty reservoirs at an estimated cost of $34,835,000, the construction of those in excess of the reservoirs approved in the Flood Control Act of 1936 was recommended by the Chief of Engineers to be deferred. The Flood Control Act of 1936 provided for an initial program of only ten reservoirs at an estimated cost of $13,373,000, the reservoir plans as described in House Document No. 412, Seventy-fourth Congress, second session, to be revised in the light of the 1936 flood. Studies of that flood revealed the need of a new program, with larger reservoirs lower down in the watershed being given higher priority. Only six such reservoirs could be built within the estimate. The inadequacy of either six or ten reservoirs is apparent from the studies of this report. The authorization of an effective system is urgent. Considerable progress has already been made in

providing levee and wall protection at seven communities on the lower Connecticut River, and it is urgent that an effective system of reservoirs be authorized and constructed at an early date in order to completely protect the areas behind the levees, and to insure that the future rapid development in the seven leveed areas will not be jeopardized by the false security engendered by a misconception that the local protective works provide complete protection. The levees alone do not offer complete protection against the design flood or against floods appreciably larger than the record flood of March 1936, and a large reservoir system in the upper watershed is needed to insure the effectiveness of the local protection and prevent the destruction of the protective works now under construction at an estimated total cost of over $20,000,000, including local costs.

86. THE REVISED PLAN FOR FLOOD CONTROL. - The essential features of the revised comprehensive plan proposed in this report include:

a. A combined and interrelated system of reservoirs and levees to protect adequately against the design flood.

b. A system of 29 reservoirs, as set forth in Table IX, controlling 4749 square miles, or 45 percent of the drainage area above Hartford. Their combined flood control capacity at spillway elevation is 1,556,780 acre-feet. This is 40 percent of the volume of the 1936 flood. The system will reduce the design flood 10.4 feet at Hartford and below the grade of the approved levee system.

c. Multiple-purpose reservoirs for flood control and conservation at Victory, Vermont; Ludlow, Vermont; and West Canaan, New Hampshire.

d. Adaptations for future power development at the Union Village, Gaysville, and Williamsville sites in Vermont, the Upper Fifteen Mile Falls site in New Hampshire, and the Knightville and Tully sites in Massachusetts.

e. Adaptations for raising the dam for future additional conservation capacity at the South Branch, Vermont, site.

f. Additional local protective works at Springfield, Springdale (Holyoke), and Riverdale (West Springfield), Massachusetts; and Winsted, Connecticut.

g. Modifications and additions to the local protective works at Hartford, East Hartford, Springfield, West Springfield, Chicopee, Holyoke, and Northampton.

87. THE ESTIMATED COSTS OF THE REVISED COMPREHENSIVE PLAN. - The estimated costs of the Revised Comprehensive Plan are shown in the following table, detailed to show costs for flood control alone and costs of adaptations, costs to the United States, and costs to local interests.

TABLE XXIII

SUMMARY OF ESTIMATED COSTS FOR REVISED COMPREHENSIVE PLAN

Project	Capital cost			Annual cost		
	Federal	Local	Total	Federal	Local	Total
Reservoirs						
Flood control	$80,291,000	$ -	$80,291,000	$4,065,600	$207,300	$4,272,900
Additional for multiple-purpose dams and adaptations	3,722,000	-	3,722,000	180,000	5,400	185,400
Levees or walls						
Proposed new	980,000	107,000	1,087,000	46,050	14,390	60,440
Present project plus modifications	17,000,000	2,100,000*	19,100,000	724,000**	367,000**	1,091,000
Channel improvements	183,000	5,000	188,000	8,130	3,680	11,810
Total	102,176,000	2,212,000	104,388,000	5,023,780	597,770	5,621,550

* Estimated from available data. The work is under way and local interests have procured and are procuring the lands and rights-of-way needed. The costs thereof are in excess of the estimates given in House Document No. 455. Local costs given are exclusive of the cost of construction of one pumping plant at West Springfield, and of sewer modifications and the construction of five pumping plants at Springfield; this work was done prior to adoption of the project, but is essentially a part thereof and occasioned thereby.

** Approximate.

Detailed estimates for the flood control costs of the reservoirs are given in Table XIII, Paragraph 43; for the levees, in Paragraphs 49 and 50 g; and for the channel improvements, in Paragraphs 57 and 58. All projects are described in detail in the Appendix. The estimated costs given above are not additional to, but inclusive of, the costs for flood control alone of the project described in House Document No. 455, i. e., $46,359,000 to the United States and $1,264,000 local costs for levees. The costs for reservoirs in that plan are $34,835,000. More extensive surveys and investigations, including especially a study of the 1938 flood, as well as the design studies of the initial dams now under construction, have shown the necessity for larger spillway capacities and

other important design changes. A revised estimate of the costs of construction of the 20 reservoirs of the approved plan would be approximately $43,063,000 plus $2,178,000 for multiple-purpose adaptations. The revised plan does not include all of the dams of the project described in House Document No. 455.

88. THE ESTIMATED FLOOD CONTROL BENEFITS. - The total average annual benefits attributable to the reservoirs of the Revised Comprehensive Plan, including direct, indirect, and restoration benefits, are $4,715,400. The total average annual benefits attributable to the Winsted Channel Improvement are $12,000. The total average annual benefits attributable to the Springdale Levee are $40,400, and to the Riverdale Levee, $18,200, assuming the full group of 29 reservoirs to be operative.

89. RATIO OF FLOOD CONTROL BENEFITS TO COSTS. - The ratio of benefits to costs is 1.10 for the reservoirs; 1.40 for the Winsted Channel Improvement; and 1.50 for the Springdale Levee.

90. POWER FEATURES. - No immediate installation of hydroelectric generating capacity is proposed. Provision is made for the ultimate installation of 142,000 kilowatts of generating capacity at three sites, when market conditions warrant. These sites are Gaysville, Vermont; Williamsville, Vermont; and Upper Fifteen Mile Falls, New Hampshire. Benefits will come from the economies made possible by the larger output. The dams at the first two sites should be built so that they may be raised in the future for power development. The dam at the third site should be built initially to the ultimate height, and the storage used for flood control until such time as it is feasible to install generating equipment to utilize a portion of the capacity for power. At such time, the capacity to be used for power generation should be replaced by other additional flood control storage within the watershed having an equal flood control effect at downstream points. Upon the recommendation of the Federal Power Commission, additional capacity will be provided at

the Knightville, Massachusetts, and the Union Village, Vermont, sites, to permit of the future development of power at these sites. In compliance with further recommendations of that Commission, the Tully dam will be constructed to permit of future raising to develop power.

91. CONSERVATION FEATURES. - The immediate installation of substantial amounts of conservation storage capacity in addition to flood control capacity is proposed at three sites where the cost of providing this extra storage is small. These sites are Ludlow, Vermont; Victory, Vermont; and West Canaan, New Hampshire. Adaptation to permit of future raising is also proposed for one other dam, South Branch, Vermont, for which possible future benefits to be derived may justify the expenditure. The operation of conservation storage will enable greater output at existing hydroelectric stations, with resultant savings, will provide water areas for recreational purposes, will improve sanitary conditions at downstream points, will increase minimum stages in the lower Connecticut River and aid navigation, and will assist in regularizing stream flow with its many advantages.

92. CONSERVATION AT EXPENSE OF LOCAL INTERESTS. - Conservation storage in the amount desired by any local interest should be provided at any site if the local interest assumes all costs in excess of the costs for the recommended flood control capacities. This is provided for by existing legislation as mentioned in Paragraph 31. State officials of Massachusetts have formally stated their desire for additional storage on this basis, at Lower Naukeag and Barre Falls sites, chiefly for pollution abatement purposes. They are studying other sites recommended herein. Likewise, New Hampshire officials are studying the question for sites in that state, chiefly for recreation purposes.

93. UNEVALUATED BENEFITS. - Losses previously discussed, and used to compute the average annual benefits, have been those easily assigned a monetary value. There are additional benefits which have not been

evaluated. No estimate has been made of the increase in annual direct losses which will result from the normal growth and development that may be reasonably anticipated even if flood protection is not provided. Protective works will provide greater benefits from the restoration of depreciated values than computed under Paragraph 15 if the works are constructed at an early date, before depreciation becomes permanent and while the loss may still be easily recovered. Enhancement benefits have been computed from the potential increase in value of unimproved lands where development has been retarded solely by floods. Greater enhancement benefits than those shown will accrue under more favorable general economic conditions. Other benefits will result from the increase in population and the building developments made feasible by protection of the flooded areas. Another class of unevaluated benefits will result from prevention of the innumerable other losses which are not susceptible of monetary evaluation. They include serious adverse effects upon the lives and security of the people and communities concerned - potential loss of life, mental and physical strain, hardship, inconvenience, and impairment of public health. In the Connecticut Valley these elements of flood experience and apprehension which may not be evaluated are of outstanding importance in view of the great floods in recent years. These elements of uncertainty determine the utilization, desirability, and future growth of the area, and form an additional justification for protective works.

94. LOCAL COOPERATION. - The need for the control of floods is keenly felt throughout the Connecticut Valley, and there is a general and active interest in obtaining protection, both in the more populous centers on the main stem and in the tributary basins. Local interests are substantially in accord with the recommended plan for flood control. Local interests have already met the legal requirements for local

participation in the cost of levees of the approved project, and have expressed their willingness to cooperate to the extent required for all levees as recommended in the Revised Comprehensive Plan. The provision of conservation storage at request of local interests is discussed in Paragraph 92.

95. COSTS FOR MULTIPLE-PURPOSE RESERVOIRS. - Flood control should not be charged with the costs of providing storage for other purposes. Where justified by prospective immediate realization of benefits, multiple-purpose dams should be initially constructed. Where the realization of benefits for other uses may be expected at a future date but cannot be realized in the near future, the present expenditure of funds for a high multiple-purpose dam is an economic loss. In such cases adaptation features which can be economically included in the design are provided. The additional funds for multiple-purpose dams immediately justified and for the adaptations included herein should be included in the authorization. If other multiple-purpose dams are authorized for initial construction, the authorization for funds should be extended to cover the additional costs based upon estimates approved by the Chief of Engineers.

96. NEED OF STATE AND LOCAL STREAM PROTECTION LEGISLATION. - Flood heights, and consequently flood damages, have been increased in all major floods, due to the failure of dams and bridges, or the encroachment on stream capacity by buildings or other structures. State and local governments should adopt such legislation, or, if such legislation already exists, enforce it rigidly, to the end that supervision may be exercised over these structures. Such legislation should provide for: authorization for new dams, bridges, or structures in or over streams, to be by state or other responsible authority, where such authorization by the United States is not now required under its jurisdiction over navigable streams; the establishment of standards for dam

design, especially adequate spillway capacity, and of standards for bridge construction, especially adequate clearances under bridges; authority for the state or local governments to require strengthening or reconstruction of weak dams and inadequate bridges; and an inspection system for structures in or over streams.

XII. CONCLUSIONS

97. a. The flood of September 1938 has conclusively demonstrated the need for greater protection against major floods in the Connecticut River Valley than that heretofore authorized. The succession of three great floods, in November 1927, March 1936, and September 1938, has caused tremendous losses and has engendered a fear in the population of the entire valley that has adversely influenced property values to a marked degree. The need is urgent for relief measures to prevent serious losses, preserve existing values, restore values that existed prior to the floods of 1927, 1936, and 1938, and maintain economic, industrial, and social stability and security.

b. Protection should be provided against a design flood having a run-off volume of approximately 6.0 inches on the watershed and producing a peak discharge of 420,000 cubic feet per second at Hartford, Connecticut, under natural conditions. Such a flood could result from a storm having the general characteristics of the September 1938 storm. The existing authorization of 10 reservoirs, as well as the deferred plan of House Document No. 455, Seventy-fifth Congress, second session, should be expanded to provide for immediate authorization for protection against the design flood of this report. The control provided in the proposed plan, substantially as described in paragraph 86, is necessary to afford adequate protection.

c. The Revised Comprehensive Plan for Flood Control proposed herein is adequately justified by the tangible and intangible benefits which it will insure, and it will provide protection to all points in the valley which have sustained major losses in the past. The benefits from the reservoirs are not restricted to localized areas, but protect all downstream communities, and it is to the best interest of the Federal

Government to assume the complete cost of all dams and reservoirs.

d. Immediate development of power is not justified at any site.

e. Future development of power may become justified at the Gaysville and Williamsville sites. Adaptations in present design to permit of this are warranted.

f. Multiple purpose dams for flood control and conservation storage are justified at the Victory, Vermont; Ludlow, Vermont; and West Canaan, New Hampshire sites.

g. Future conservation storage may become justified at the South Branch, Vermont, site. Adaptations in present design to permit of this are warranted.

h. The cost of providing storage at flood control dams, for other purposes, should not be charged against flood control. Additional funds should be authorized to cover all costs in excess of flood control costs for multiple-purpose reservoirs recommended for initial construction, and for the adaptations included herein on dams recommended for future development.

i. Flood control reservoirs furnish numerous sanitation benefits, but additional storage solely for pollution abatement is not considered justified for provision of the cost thereof by the Federal Government. The pollution situation is briefly described previously in this report and fully covered in Section 3 of the Appendix. The remedial and abatement measures described are suggested to State and other local authorities for their consideration to the extent applicable.

j. State and local governments should adopt and enforce legislation providing for supervision over dams, bridges, and other structures in or over streams in order to reduce or prevent further encroachment on flood channels and the resultant increase to the flood menace.

XIII. RECOMMENDATIONS

98. It is recommended:

a. That the present flood control project for the Connecticut River be modified to provide for a revised comprehensive flood control plan substantially as described herein to include: (1) the construction of 29 reservoirs at the approximate locations shown herein, at an estimated cost of $84,013,000, of which $80,291,000 is for flood control and $3,722,000 is for the extra cost of multiple-purpose dams or adaptations therefor; (2) the construction of additional flood control protective works at Winsted, Connecticut, and Springdale (Holyoke), Springfield, and Riverdale (West Springfield), Massachusetts, substantially as described herein at an estimated cost to the United States of $1,163,000 and to the local interests of $112,000, provided that local interests furnish without cost to the United States all lands, easements, and rights-of-way, hold and save the United States free from damages due to the construction works, maintain and operate all the works after completion; and (3) an increase in the authorization for local protective works at Hartford, East Hartford, Springfield, West Springfield, Chicopee, Holyoke, and Northampton to an estimated cost of $17,000,000 to include changes of alinement at Hartford and East Hartford as described herein; the estimated costs given above being inclusive of the estimated costs of the existing project;

b. That the Chief of Engineers be authorized to substitute other reservoirs of approximately the same flood protection value for those herein recommended, if, in his opinion, such substitution is desirable in the interest of effective flood protection;

c. That the Chief of Engineers be authorized to construct multiple-purpose dams at any of the sites listed herein, to provide for

additional storage, in excess of the proposed flood control storage, for conservation for recreation, pollution abatement, or other purposes, provided local interests so request and contribute the excess cost of such additional capacity prior to construction, in accordance with the provision of Section 5 of Public No. 738, Seventy-fourth Congress (1936 Flood Control Act) as amended by Act of July 19, 1937;

d. That at such time as the use of Upper Fifteen Mile Falls as a multiple-purpose dam becomes justified, a minimum capacity of approximately 260,000 acre-feet, the equivalent of 3.0 inches of run-off from the watershed, be retained for flood control purposes, and the authorization for flood control reservoirs be increased to provide additional flood control storage at other locations in such amount as to insure equivalent flood protection at downstream points, the requisite additional storage to be provided by reservoirs approved by the Chief of Engineers;

e. That the authorization recommended in Paragraph a, above, be increased as necessary to cover all costs in excess of flood control costs, for such additional multiple-purpose reservoirs or adaptations therefor as may be authorized for construction in elaboration of this plan, other than those already provided in the plan, except as provided in Paragraph c, above; such increase to be in accordance with estimates approved by the Chief of Engineers.

J. S. BRAGDON
Lieut. Col., Corps of Engineers
District Engineer

Inclosures:
Appendix, in three volumes
Records of 5 hearings
(6 copies of each)

Comm. E. 20/107.15 Subject: Review of Reports on Flood Control, Connecticut River.

1st Ind.

Office, Division Engineer, NORTH ATLANTIC DIVISION, New York City, May 12, 1941 - To the Chief of Engineers, U. S. Army.

1. Flood losses in the Connecticut Valley have been especially severe in recent years. The floods of November 1927, March 1936, and September 1938, caused direct damages of $15,926,000, $34,900,000, and $25,396,000 respectively. Property valued at approximately $393,498,000 was affected by the floods of 1936 and 1938. Data obtained since the 1938 flood indicate that the expectancy of severe floods is greater than was estimated in the comprehensive plan published in House Document Numbered 455, Seventy-third Congress, Third Session, and approved by the Flood Control Act of 1938. Based on revised expectancy of flood occurrence, the estimated average annual direct damages from floods are $1,799,000, and the indirect are $1,353,000. The District Engineer estimates that the floods of 1936 and 1938 caused a decrease in property values of approximately $83,739,000 in addition to the capitalized direct and indirect losses. He estimates that one-half of this depreciation loss can be restored by adequate flood protection and that on this basis the annual value of recoverable depreciation is $2,932,000.

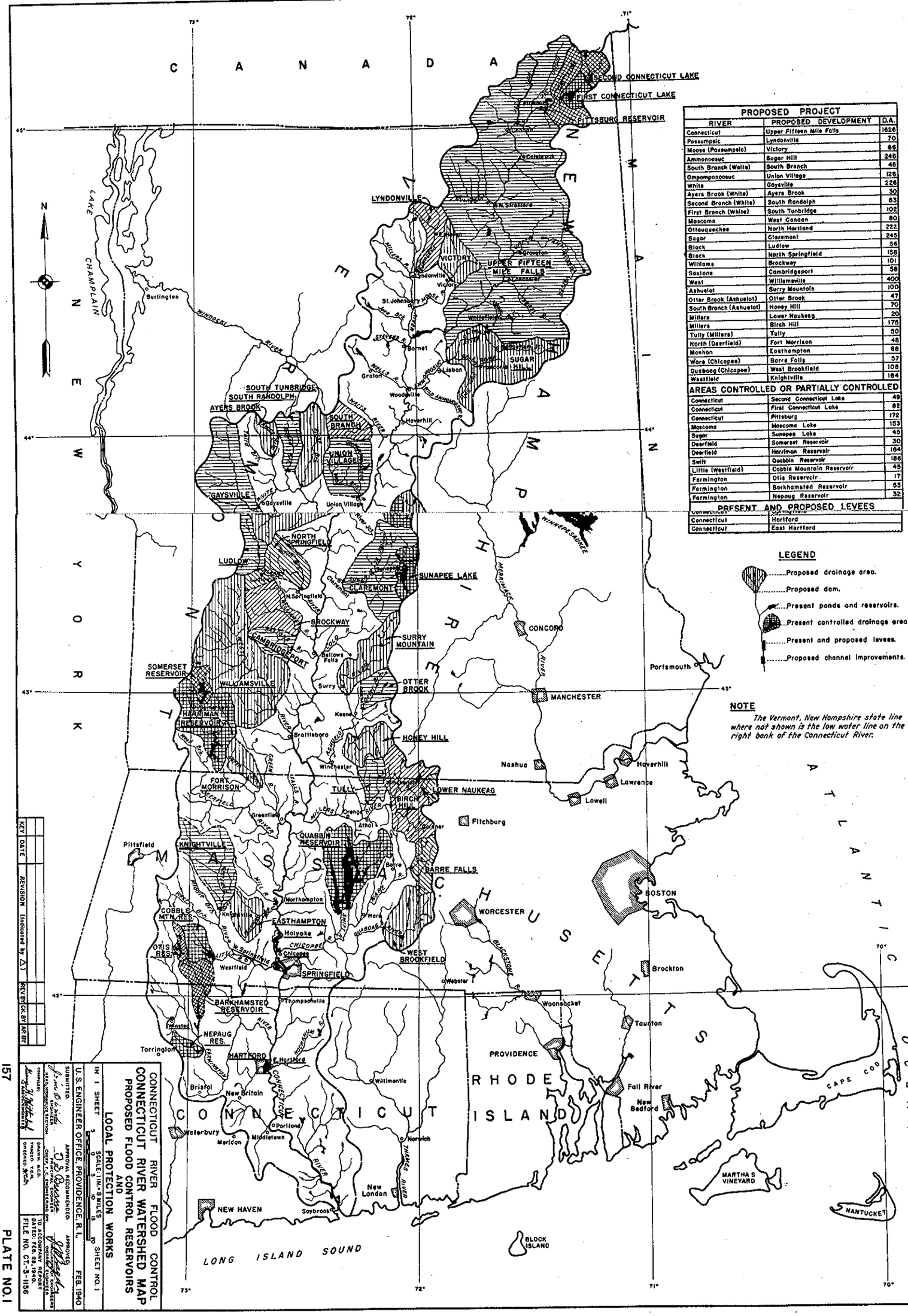
2. The Flood Control Act of 1936 authorized the construction of an initial system of ten reservoirs at an estimated cost of $13,373,000. The Flood Control Act of 1938 approved a project which provided for the construction of twenty reservoirs on tributaries of the Connecticut River and local improvements at Hartford and East Hartford, Connecticut; Springfield, West Springfield, Chicopee, Holyoke, and Northampton, Massachusetts, and authorized the local improvement projects at a cost not to exceed $11,524,000.

3. A modification of the authorized local protection project for the seven localities was submitted to Congress in House Document Numbered 653, Seventy-sixth Congress, Third Session. The estimated cost of the modified local protective works is $17,000,000. A modification of the approved reservoir plan has been submitted to Congress in House Document Numbered 794, Seventy-sixth Congress, Third Session. The plan provides also for certain additional local works. The existing project and recommended revisions include twenty reservoirs at an estimated cost of $57,460,000, and local protection works at an estimated cost to the United States of $15,070,000.

4. In the report under consideration, the District Engineer recommends a modification of the present flood control project to include the construction of nine reservoirs in addition to the twenty recommended in House Document Numbered 794, at an estimated cost of $24,013,000 for the twenty-nine reservoirs; local protection works at Winsted, Connecticut, Springdale (Holyoke), Riverdale (West Springfield), and Springfield (Mill River), Massachusetts, at an estimated cost to the United States of $1,163,000; and an increase to $17,000,000 in the authorization for local protection works at the seven localities. All of the local protection works proposed in the review report have been recommended in House Documents Numbered 794 and 653. The plan which has been recommended to Congress consisting of twenty reservoirs and all of the local protection projects proposed in this report will be referred to as the Modified Approved Plan. The complete works proposed in the District Engineer's review report will be referred to as the Enlarged Plan.

5. Pertinent data for comparison of the two plans are given in the following table:

	Modified Approved Plan	Enlarged Plan
RESERVOIRS		
No. of reservoirs	20	29
Control of drainage area above Hartford	26%	43%
Construction Cost	$ 34,114,000	$ 54,247,000
Cost of lands and utility relocations	20,231,000	26,044,000
Total cost for flood control	54,345,000	80,291,000
Additional cost for future power	3,115,000	3,722,000
Total reservoir cost	57,460,000	84,013,000
LOCAL PROTECTION		
Construction Cost	$ 18,070,000	$ 18,163,000
Lands and rights-of-way	2,215,000	2,212,000
Total cost	$ 20,285,000	$ 20,375,000
Total cost entire project	$ 77,745,000	$104,388,000
Total cost to United States	75,530,000	102,176,000
Annual charges flood control	4,082,000	5,436,000
Annual Benefits, Flood Control		
Direct	$ 1,215,000	$ 1,298,000
Indirect	1,063,000	1,136,000
Restoration of values	2,008,000	2,776,000
Total	$ 4,286,000	$ 5,210,000
Ratio of annual benefits to annual costs:		
(a) Based on total benefits	1.06	0.96
(b) Based on direct and indirect benefits	0.56	0.45
Average annual direct and indirect damages prevented	68%	73%



PROPOSED PROJECT		
RIVER	PROPOSED DEVELOPMENT	D.A.
Connecticut	Upper Fifteen Mile Falls	1626
Passumpsic	Lyndonville	70
Moose (Passumpsic)	Victory	66
Ammonoosuc	Sugar Hill	246
South Branch (Wells)	South Branch	46
Ompompanoosuc	Union Village	126
White	Gaysville	226
Ayers Brook (White)	Ayers Brook	30
Second Branch (White)	South Randolph	63
First Branch (White)	South Tunbridge	102
Mascoma	West Canaan	80
Ottauquechee	North Hartland	222
Sugar	Claremont	245
Black	Ludlow	56
Black	North Springfield	156
Williams	Brockway	101
Saxtons	Cambridgeport	58
West	Williamsville	400
Ashuelot	Surry Mountain	100
Otter Brook (Ashuelot)	Otter Brook	47
South Branch (Ashuelot)	Honey Hill	70
Millers	Lower Naukeag	20
Millers	Birch Hill	175
Tully (Millers)	Tully	50
North (Deerfield)	Fort Morrison	48
Monhan	Easthampton	68
Ware (Chicopee)	Barre Falls	57
Quaboag (Chicopee)	West Brookfield	108
Westfield	Knightville	164
AREAS CONTROLLED OR PARTIALLY CONTROLLED		
Connecticut	Second Connecticut Lake	49
Connecticut	First Connecticut Lake	82
Connecticut	Pittsburg	172
Mascoma	Mascoma Lake	153
Sugar	Sunapee Lake	45
Deerfield	Somerset Reservoir	30
Deerfield	Harriman Reservoir	164
Swift	Quabbin Reservoir	186
Little (Westfield)	Cobble Mountain Reservoir	45
Farmington	Otis Reservoir	17
Farmington	Barkhamsted Reservoir	53
Farmington	Nepaug Reservoir	32
PRESENT AND PROPOSED LEVEES		
Connecticut	Hartford	
Connecticut	East Hartford	

LEGEND

- Proposed drainage area.
- Proposed dam.
- Present ponds and reservoirs.
- Present controlled drainage area.
- Present and proposed levees.
- Proposed channel improvements.

NOTE

The Vermont, New Hampshire state line where not shown is the low water line on the right bank of the Connecticut River.

KEY	DATE	REVISION (Indicated by △)	REVISED BY	APP BY

CONNECTICUT RIVER FLOOD CONTROL

CONNECTICUT RIVER WATERSHED MAP PROPOSED FLOOD CONTROL RESERVOIRS AND LOCAL PROTECTION WORKS

U.S. ENGINEER OFFICE, PROVIDENCE, R. I., FEB. 1940

SCALE: 1 IN. = 8 MILES (0 5 10 15 20)

SHEET NO. 1 IN 1 SHEET

SUBMITTED: APPROVAL RECOMMENDED: APPROVED:

DRAWN: H.C.D. TRACED: T.C.H. CHECKED: J.C.S.

TO ACCOMPANY REPORT DATED: FEB. 28, 1940.

FILE NO. CT.-3-1156

6. The greatest single addition proposed under the Enlarged Plan is the Upper Fifteen Mile Falls Reservoir which controls a drainage area of 1,626 square miles, or approximately 16% of the total drainage area above Hartford. The shape of the watershed and the direction of travel of the prevailing storms are such that the flows from the area above Fifteen Mile Falls do not contribute greatly to the peak flows of the lower watershed. During the 1936 flood, the peak flow from this area reached Hartford about two days after the major crest had passed.

7. The Modified Approved Plan of reservoirs and local protection works will reduce the average annual direct and indirect flood losses by about 68%. The reservoirs will have a flood control storage capacity of 939,950 acre feet, and will control 2,752 square miles. Existing water supply and power projects provide partial control of an additional 651 square miles. Excluding the area above Fifteen Mile Falls, which has little effect on stages along the lower river, 38% of the area above Hartford will be under control. Except at Hartford, Connecticut, the major damage centers for which local protection works are provided will be protected against a flood having an estimated probability of occurrence of 0.1 of 1% in any year, or approximately 30% larger than the largest of record. At Hartford, the increased height of dikes, provided through local cooperation, will protect against a flood with a probability of occurrence of 0.04 of 1% in any year, or approximately 45% larger than the largest of record.

8. The Enlarged Plan will prevent about 73% of the average annual direct and indirect damages to the valley from floods. The reservoirs will provide a total flood control storage capacity of 1,556,780 acre feet, and control 4,749 square miles or 49% of the total drainage area above Hartford. Existing storage reservoirs provide a large measure of control for an additional 999 square miles, increasing the control to about 90% of the area above Hartford. The average annual direct and indirect benefits of the Enlarged Plan will be $156,000 greater and the annual charges will be $1,374,000 greater than those of the Modified Approved Plan.

9. It is noted in the District Engineer's report, that more than one-half of the benefits accredited to the Enlarged Plan is restoration of pre-flood values. Approximately 90% of the loss in values is claimed for the seven localities for which local protective works are now under construction. Much of these losses as exist should be largely recovered by the high degree of protection provided by the Modified Approved Plan.

10. The Modified Approved Plan will provide a high degree of protection, particularly at the major damage centers. The additional cost of the Enlarged Plan now recommended by the District Engineer is much greater than the additional benefits to be derived from this plan. I do not concur in the recommendation to increase the plan at this time.

11. I recommend that the existing project for flood control on the Connecticut River and tributaries be modified to provide for the construction of the twenty reservoirs and local protective works, as described in House Document Numbered 724, Seventy-sixth Congress, Third Session, and House Document Numbered 653, Seventy-sixth Congress, Third Session, subject to such minor changes as may later be found advisable by the Chief of Engineers, at an estimated cost to the United States of $75,530,000: Provided, that for the local protection works, responsible local interests shall furnish without cost to the United States, all lands, easements, and rights-of-way, necessary for the construction; hold and save the United States free from damages due to this construction; and maintain and operate the works after completion in accordance with regulations prescribed by the Secretary of War.

J. N. HODGES
Colonel, Corps of Engineers
Division Engineer

Inclosures:
Comm. N. 20/107.15-a to e (Appendices)
14 copies of each Appendix (Sep. Cover)
(Serial Nos. 1 to 14 inclusive)